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EPA

The Ecological Impacts Of Wastewater On Wetlands

An Annotated Bibliography

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The report is an annotated compilation of references, nationwide, on the ecological effects of wastewater addition to wetlands. In addition to over 1000 entries, the document contains an introduction to the ecological issues and bibliographic research methods, a study guide highlighting leading references and an index to subjects, key words and geographical locations.

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IV. Index (following entry number 1097)........................ I

The most recent additions to the bibliography are located at the end of Section III, following entry number 1065. New citations are separately alphabetized and numbered in sequence with the previous entries, beginning with number 1066. For the reader's convenience, these new entries have been inserted in proper alphabetical order into the main entries by author and date.

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I. INTRODUCTION

This annotated bibliography is a compilation of references on the ecological impacts of wastewater addition to wetlands. It is organized into four sections. The introduction develops the background of wastewater application to wetlands, provides an overview of the ecological issues involved and gives a summary of methods, materials and problems encountered with compiling the references and abstracts for this publication. A study guide section provides an overview discussion of wetlands and wastewater, with key references for those who are unfamiliar with these topics. The third and largest section of the document is an alphabetical and numerical listing of entries and abstracts. These are arranged by the author's last name. The final section is an index to subjects, key words and geographical locations.

Background

The United States faces the critical task of improving the Nation's water quality while containing the costs of water pollution control. Over the years conventional wastewater treatment has been based largely on expensive and complicated "high technology" practices. Typically, secondary treatment standards are achieved by expensive and complicated processes such as activated sludge or trickling filters. This is followed by a settling step and the discharge of treated effluent to surface waters. The solids produced by wastewater treatment, called sludge, must be disposed of by incineration, land application, landfill or ocean dumping. Such conventional treatment systems are well understood and widely accepted by the sanitary engineering community. However, such operations often are dependent on large amounts of energy, sophisticated equipment, chemicals and capital investments, which make them expensive to operate and maintain, particularly for smaller towns. The wastewater treatment lagoons, frequently used by small communities, can provide reasonably priced secondary treatment, but this treatment level is not always sufficient to meet necessary effluent limitations. In areas of low stream flow, lake discharge or other special demands for water quality improvement, the need to implement more advanced treatment (such as removal of nutrients, additional organics and suspended solids) compounds the problems and costs of wastewater treatment. Recent attention has been given to the economic difficulties of achieving adequate treatment in existing conventional facilities, especially if advanced treatment levels are required. Sophisticated conventional treatment methods may not succeed in controlling water pollution if the facilities are too difficult or expensive for the owner or community to maintain and operate at the treatment level for which they were designed.

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These economic pressures have intensified the search for creative, cost-effective and environmentally sound ways to control water pollution. In this context, more attention has been given to developing alternative approaches to the treatment of wastewater. The Clean Water Act Amendments of 1977 and 1981 have encouraged innovative and alternative treatment technologies, especially for small communities. One technical approach is to use managed, natural and artificially constructed ecosystems as a functional part of wastewater treatment. For example, land treatment of wastewater, which was the only recognized technology before the advent of current sanitary engineering solutions, is being reconsidered and further developed as an effective form of wastewater treatment and pollution control. Wastewater has been successfully utilized as a water and nutrient resource in agriculture, silviculture, aquaculture, golf course and green belt irrigation and other areas. Sludge has been used in forest and agricultural crop production to reclaim and restore strip-mined lands and other heavily disturbed areas. An additional bonus to innovative and alternative technologies is the approach to wastewater as a resource rather than a liability. Productive reuse and recycling of the wastewater is realized from many of these technologies.

Using Wetlands

Although wetlands have traditionally been viewed as unproductive areas without significant value, much information on the ecological functions and natural values of these areas has been documented during the last few decades. Wetlands serve as water reservoirs, as links between surface and ground water, and as modulators and filters in the hydrologic cycle. They are vital to fish and wildlife, and may serve as critical habitat for rare and endangered species. Recreational, aesthetic and scientific values are also contributed by wetlands. The role of wetlands in global biochemical cycling and atmospheric stability may be substantial. A special Federal interest in protecting and enhancing wetlands has been recognized in Executive Order 11990, "Protection of Wetlands", May, 1977 and in policies developed by various Federal agencies.

Currently, the water purification ability of wetlands is receiving special notice. It is anticipated that this natural function can be harnessed for use in the renovation of wastewater. The idea that wetlands could be useful as a functional part of wastewater treatment has developed partly as an extension of the basic land treatment concept and partly as an effort to improve the existing unit process approach to wastewater treatment. Constructed units, termed "artificial" wetlands, have been created specifically for wastewater treatment. In some cases wetland plant species have been added to existing sewage lagoons while at other sites new wetlands have been constructed. At still other locations, natural wetlands now function as an

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integral part of the treatment facilities. These efforts have shown that wetlands can achieve very high levels of treatment as well as provide other values. Some small communities in areas with extensive wetland acreages and few large streams for effluent discharge may be able to make use of the natural wetland resource to renovate their wastewater. In other regions where much of the original wetlands have been destroyed or degraded, there is an opportunity to use wastewater in wetland restoration. This planned use of wetlands for wastewater treatment contrasts with the unplanned and frequently underdesigned discharges of wastewater to wetlands found at some locations. In several parts of the United States where inventories have been conducted, these unplanned discharges are more prevalent than newer, well designed systems - often something that "just happened" at a time when wetlands were less well understood and appreciated.

Ecological Concerns

Although wetlands have been recognized by natural scientists as offering some potential for treating wastewater, work on the engineering aspects has outpaced an ecological understanding of the strengths, limitations and overall aspects of wetland treatment. This situation is compounded when system planners are tempted to take a "cookbook" approach to applying wastewater to wetlands in the treatment process, not recognizing the variability among different wetland types and site-specific biological and hydrological conditions. Some wastewater treatment applications have led to severe ecological disruptions, while others have had at least short term success, without evidence of ecological problems. Little research on the ecological aspects of wastewater addition to wetlands has been undertaken to date, especially on long term effects. This ecological understanding is essential to developing a decision process to determine when a wetland alternative is workable and when it is unwise.

This imbalance between engineering knowledge and ecological understanding has created opposition, by some, to the use of wetlands in the treatment of wastewater. Potential negative ecological impacts resulting from the use of wetlands must be fully considered. Beneficial effects of wastewater treatment and the potential enhancement of wetlands and water bodies also merit complete consideration. Attempts to assess ecological effects have been confronted both by problems of understanding natural processes in wetlands and by the difficulty of locating available ecological information on wetlands and wastewater topics.

This annotated bibliography is an effort to help provide the information necessary to develop appropriate wetland treatment techniques based on an understanding of wetland ecology. General topics that are covered include:

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1) health concerns - human and wildlife, 2) effects of toxic substances, 3) adverse community changes, 4) effects on other wetland functions and values, 5) long-term effects, 6) management potential, and 7) research needs.

Bibliographic Research Methods

Entries in the bibliography were obtained from a wide range of sources, primarily conference and symposia proceedings, government publications, research reports, and scientific journals. The entry titles were collected from those sources, prepared bibliographies, and computer data bases (Table 1). A standardized list of key words used for all the data base searches was developed (Table 2). Approximately 55 percent of the entries have been annotated. The original author abstract was used whenever possible; otherwise an abstract was written from the report itself or an abstract from one of the data bases was used. Each abstract is followed by two letters that identify its source. A key to these letters is found at the beginning of the list of entries (Table 3).

Table 1. Primary sources of references for the wastewater/wetland bibliography.

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*DIALOG Information Retrieval Service
    Environmental Bibliography
    BIOSIS (Biological Abstracts)
    Aqualine
    Enviroline
    NTIS (National Technical Information Service)
    Pollution Abstracts
    IRL Life Sciences Collection

*Numerous conference and symposia proceedings, including St. Paul, Minnesota 1981 and 1983 and Amherst, Massachusetts, 1982.

*U.S. Environmental Protection Agency. 1983. The Effects of Wastewater Treatment Facilities on Wetlands in the Midwest. Region V. EPA 905/3-83-002. Technical Report. Chicago.

*US Environmental Protection Agency, 1983. Environmental Impact Statement. Phase I Report - Freshwater Wetlands for Wastewater Management. EPA 904/9-83-107. Region IV, Atlanta.

*Water Resources Abstracts

*Wetland Values Bibliography - U.S. Fish & Wildlife Service, Western Energy & Land Use Team.

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Two problems were encountered in locating relevant references. The first was difficulty in locating applied materials on wetlands. Much of the needed information is in a "gray area" of literature which is difficult to assess. No single journal focuses on this topic so one must search for items in both biological and engineering journals, government reports, wetland symposia and other similar sources. Such a diversity of literature does not always show up in computerized data bases because it lies between standard ecological and engineering disciplines. Computer data base searches also pose problems because the terms used to describe wetlands are diverse and confusing. Frequently these are regional names like pothole, pocosin, playa/lake, vernal pool, slough, and bottomland hardwood, to name a few. Sometimes wetlands are included with an aquatic system, like river, lake, or pond; at other times they are described as littoral areas. Artificial (constructed) wetland terms also are plentiful - lagoons, farm ponds, aquaculture, hydroponics, as well as others.

Table 2. Computer database search descriptors used in locating references.

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wastewater
sewage
water treatment
effluent
nutrient removal

wetland
swamp
marsh
bog
lagoon
aquaculture
estuaries
riverine
riparian

Each of the descriptors in the first column was paired with each descriptor in the second column for one search of the entries in each data base.

The second problem, of equal difficulty, was limiting the scope of the bibliography without sacrificing useful material. Few publications describe solely ecological impacts of wastewater on wetlands. Considerable information is available on peripheral subjects that provide insights into wetland/wastewater issues. These include a variety of research reports on aquaculture, an overwhelming volume of material on pollution in aquatic ecosystems (eutrophication, heavy metals, etc.), and considerable information on land treatment of wastewater and sludge, as well as research on conventional wastewater treatment practices. This selected bibliography will focus on references that deal directly with the use of wetlands, or with the use of aquatic plants and animals, in the treatment of wastewater or the improvement of water quality. Treatment of the foreign literature is extremely limited in this document, an area which would be worthwhile to pursue in greater detail.

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Table 3. Key to the two-letter code to abstract sources.

Code Letters	Source
AA	Author's abstract or adapted from author's abstract
AL	Aqualine, DIALOG Information Retrieval Service
BA	BIOSIS, Biological Abstracts, DIALOG Information Retrieval Service
DM	Monge, D. 1978. Bibliography of Wetland Values. School of Forestry. State University of New York, Syracuse.
EB	Environmental Bibliography, DIALOG Information Retrieval Service
EL	Enviroline
EP	USEPA, 1983 (Region V).
NT	National Technical Information Service, DIALOG Information Retrieval Service
PA	Pollution Abstracts, DIALOG Information Retrieval Service
WE	Western Energy and Land Use Team, U.S. Fish and Wildlife Service
WR	Water Resources Abstracts

A SPECIAL NOTE:

As of this writing (Fall, 1983) EPA is drafting several generic Environmental Impact Statements (EIS) on wastewater and wetlands. Call or write directly to learn more about these EIS's and to be included on their mailing lists.

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STUDY GUIDE FOR WETLANDS AND WASTEWATER TREATMENT

This section provides a guided entry into the subject matter of the Annotated Bibliography. The guide also may be of value to those who wish to review current knowledge. Key references introduced under each subheading serve as starting points for further research and are not meant to be comprehensive. The references at the end of the Study Guide that address general wetland information have been excluded from the Annotated Bibliography. All of the references pertinent to the wetlands and wastewater treatment topic are marked for the reader's convenience.

Wetland Ecosystems

Many types of wetland ecosystems exist throughout the United States and any understanding of their functions must begin with a knowledge of how these wetlands are classified. A variety of classification schemes has been developed since the 1950s, several of which are introduced here. Shaw and Fredine (1956) in Circular 39 identified 13 wetland types based primarily on the needs and requirements of waterfowl. Regional classification schemes have been developed, such as for the Northeast (Golet and Larson, 1974) and the Prairie Pothole Region of the Upper Midwest (Stewart and Kantrud, 1971). More recently, the U.S. Fish and Wildlife (USFWS) Service developed a classification system, based upon ecological characteristics of a wetland, that was used in the National Wetland Inventory (Cowardin et al., 1979).

A primary concern in any wetland manipulation is the nature and extent of the resultant system impacts. Wetlands serve an important role in the provision of habitat, in nutrient cycling, and in the flow regimes of both surface and groundwater. Increasing attention is being given to their value and sensitivity. Several books address general and/or specific wetland ecosystem impacts. Greeson et al. (1979) provides a comprehensive look at the diverse aspects of wetlands - scientific, social political, and economic. Ecological processes and management potential of freshwater wetlands are discussed by Good et al. (1978) and Richardson (1981). Weller (1981) provides a perspective on the ecology and wildlife management potential in freshwater marshes. Kusler (1983) gives an overview of wetland values and outlines protection strategies.

Wetland Treatment Capability

The concept of utilizing biological and ecological processes found in the natural environment to treat wastewater is not new. Applying wastewater and sludge to the land has evolved from the routine agricultural practices of re-

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cycling manure and other agricultural residues. Tourbier and Pierson (1976) provide a good overview of these concepts and practices as well as the U.S. Environmental Protection Agency (USEPA) in several process design manuals (US EPA, 1981; USEPA, 1983b).

With regard to its regulatory responsibilities, the USEPA has been pursuing a "technology based" approach to controlling water pollution and considers natural treatment systems, such as wetlands, well suited to meet their goals. The concept has been shown to be viable and qualifies under current USEPA definitions as innovative or alternative technology. Bastian and Benforado (1983) discuss the eligibility of this emerging technology for Federal grant assistance.

The capability of wetlands to renovate wastewater and to tolerate effluent discharges has been demonstrated in a variety of natural and artificial (constructed) wetlands across the nation. Full-scale aquatic treatment systems, as well as numerous research and development projects, are operating or under construction in over a dozen states and in several foreign countries. These include natural and constructed wetlands, treatment ponds, systems using floating aquatic plants grown in ponds or ditches, and aquaculture operations involving a variety of freshwater or marine organisms. The University of Michigan (northern peatlands and cattail marshes) and the University of Florida (cypress domes and strands) received funding during the 1970s from the National Science Foundation (NSF) to conduct long term studies on wetland treatment systems. Many other universities are involved in similar research including, but not limited to, the Louisiana State University (southern hardwood swamps), Humboldt State University, California (artificial freshwater wetlands), Rider College and Rutgers University, New Jersey (freshwater tidal marshes), the University of California - Davis (artificial freshwater wetlands) the University of Wisconsin (northern peatlands and cattail marshes), and Woods Hole Oceanographic Institute, Massachusetts, (coastal brackish water wetlands). Several publications provide lists of currently operating wetland treatment systems (Chan et al., 1982; Hammer et al., 1983; USEPA 1983d).

A number of types of natural wetlands have been used to investigate the effectiveness and ecosystem impacts of wastewater application. Northern wooded swamps, cattail marshes, southern cypress swamps, freshwater tidal marshes, salt marshes, and others have been manipulated. Artificial or constructed wetlands have recently been used in the treatment of wastewater. Listings for all of these types of wetlands can be found in the Index of this document. The use of artificial systems shows great promise for more general application across the country. They are more reliable and involve less risk of adverse environmental impact because of better process control. The use of artificial water hyacinth systems was pioneered by Wolverton and others at the NASA lab in Bay St. Louis, Mississippi (Wolverton et al., 1975). Constructed wetlands also include aquaculture systems that both treat wastes and produce valuable aquatic plants or animals, and marine polyculture systems which use wastewater and several organisms in a marine food chain relationship (Bastian and Reed, 1979).

Bastian and Reed (1979; and Reed and Bastian, In Press) provide an engineering perspective on the capability of wetland systems to renovate wastewater. Other engineering assessments have been written by Chan et al., (1982), Hyde et al., (In Press), and Tchobanoglous and Culp (1980). Under the right conditions wetland systems can achieve high removal efficiencies for BOD, suspended solids, trace organics and heavy metals. However, specific factors responsible for such high treatment levels are not clearly understood. The relationship between wastewater nitrogen and phosphorus application rates and the efficiency of nitrogen and phosphorus removal by wetlands is described by Nichols (1983). An extensive list of references on the capacity of natural wetlands to remove nutrients from wastewater is included in this article.

Criteria for Design and Ecological Management

A major engineering limitation is that optimum, cost-effective design criteria for such wetland treatment systems are not applicable across the country. Progress is being made in this area of research. Published data have been analyzed to identify general principles for the successful design and operation of wetland facilities (Hammer and Kadlec, 1983; Hammer et al., 1983; Heliotis, 1981). In both of the Hammer papers, variables in the wetland treatment process are manipulated in models which may provide more generally applicable design criteria. The Heliotis thesis includes a detailed literature review.

Richardson and Nichols (In Press) present ecological management criteria that should be addressed prior to the selection of a wetland treatment system. These criteria include the value of the effluent as a resource, the capabilities and limitations of wetlands to accomplish wastewater treatment, wastewater management objectives, wastewater suitability for wetland discharge and wetland values. Benforado (1981) and Reed and Kubiak (In Press) discuss ecological considerations in the overall wetlands manipulation process.

Several general papers provide broad perspectives on a specific topic. Tchobanoglous et al. (1979) has written an overview on the use of aquatic plants and animals in wetland wastewater treatment systems. Kadlec and Tilton (1979) reviewed the use of freshwater wetlands as an alternative to tertiary wastewater treatment.

A number of symposia and/or conferences on wetlands and their role in wastewater treatment have been held. Three of the more recent and important conferences on this subject are: (1) The Midwest Conference on Wetland Values and Management held June 17-19, 1981, in St. Paul, Minnesota; (2) The Fourth Annual Meeting of the Society of Wetland Scientists held June 5-8, 1983 in St. Paul, Minnesota; and (3) Ecological Considerations in Wetlands Treatment of Municipal Wastewaters, a Workshop at the University of Massachusetts held June 23-25, 1982, in Amherst, Massachusetts. Papers presented at these meetings or published proceedings have provided major contributions to the understanding of wetland treatment systems and their role in wastewater management.

A number of Federal agencies are interested and have been involved to various degrees in funding or coordinating research on the use of wetlands for wastewater treatment. These agencies include, among others, the National Aeronautic and Space Administration (NASA), NSF, USEPA and USFWS. The latter two agencies co-sponsored the 1982 Amherst Workshop. Some of the notable USEPA funded research has come from the Municipal Environmental Research Lab (MERL) in Cincinnati, Ohio and the Robert S. Kerr Research Lab in Ada, Oklahoma. The Ada Research Lab has funded projects in Santee, California (San Diego Regional Water Reclamation Agency), at the University of Wisconsin, Milwaukee, and in Bay St. Louis, Mississippi, as well as others. The work cited earlier by Hammer and Kadlec (1983) was sponsored by the Robert S. Kerr Lab.

USEPA is currently conducting studies that address wetlands and wastewater on a regional basis (Regions V and IV). A Region V interim document describes the effects of wastewater treatment facilities on wetlands in the six midwestern states (USEPA, 1983c). This work provides the background information needed in preparation for a Generic Environmental Impact Statement (EIS) on guidelines for wetland treatment systems. A Region IV EIS assesses the use of freshwater wetlands for wastewater disposal in the southeastern states (USEPA, 1983a). The second phase of the report, when published, will develop a handbook to delineate methods of analysis as well as safeguards and guidelines for evaluating, selecting, permitting, and monitoring wetland disposal systems. Both USEPA documents provide good overviews and have extensive bibliographies.

Institutional Considerations

Institutional constraints can severely limit the ability of regulatory agencies to implement otherwise sound concepts and technology. Critical institutional considerations concerning the use of wetlands for wastewater treatment include a) regulatory policies concerning conflicts between wetland protection and use, b) ownership and proprietary rights of private wetlands, and

c) various agency regulations and policies associated with permitting processes. While no comprehensive studies have addressed this vital aspect of wetlands and wastewater, insights may be obtained from Kusler (1980, 1983) Rusincovitch (In Press) and publications of the National Wetland Newsletter, Environmental Law Institute, Washington, D.C. Reed and Kubiak (In press) present a formal ecological evaluation process to determine wetland suitability for wastewater treatment and discharge. They further discuss how formalized wetland criteria can be adopted into the institutional framework of the facilities planning process. In addition, both USEPA regional studies will explore this topic.

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* 26. Tourbier, J. and R.W. Pierson (ed.). 1976. Biological Control of Water Pollution. Univ. of Pennsylvania Press. Philadelphia.

27. U.S. Environmental Protection Agency. 1981. Process Design Manual for Land Treatment of Municipal Wastewater. EPA 625/1-81-013.

* 28. U.S. Environmental Protection Agency. 1983a. Freshwater Wetlands for Wastewater Management. Environmental Impact Statement. Phase I Report. EPA 904/9-83-107. Region IV, Atlanta.

29. U.S. Environmental Protection Agency. 1983b. Process Design Manual for Land Application of Municipal Sludge. EPA 625/1-83-016. October.

* 30. U.S. Environmental Protection Agency. 1983c. The Effects of Wastewater Treatment Facilities on Wetlands in the Midwest. Technical Report. Region V. EPA-905/3-83-072. September.

* 31. U.S. Environmental Protection Agency. 1983d. Wetlands Treatment: A Practical Approach. (Brochure) EPA Emerging Technology Series.

32. Weller, M.W. 1981. Freshwater Marshes: Ecology and Wildlife Management. University of Minnesota Press, Minneapolis, MN. 146 p.

* 33. Wolverton, B.C., R.M. Barlow and R.C. McDonald. 1975. Application of Vascular Aquatic Plants for Pollution Removal, Energy and Food Production in a Biological System. NASA. NSTL. Bay St. Louis, MS.

° Key references on wetlands/wastewater found in Bibliography.

* Key references on wetlands/wastewater found in Bibliography with annotation.

1. Abel, P. D. 1974. Toxicity of Synthetic Detergents to Fish and Aquatic Invertebrates. J. Fish. Biol. 6(3):279-298.

Synthetic detergents are reported to be acutely toxic to fish in concentrations between 0.4 and 40 mg/l. Factors affecting toxicity include the molecular structure of the detergent, water hardness, temperature and dissolved oxygen concentration; the age and species of the test fish, and acclimation to low concentrations of detergent. Some of these factors appear to be of only limited importance. Gill damage is the most obvious acute toxic effect; the immediate cause of death may be asphyxiation, but detergents may also be toxic internally. Lethal effects not related to gill damage have not been investigated. Sublethal effects include retardation of growth, alteration of feeding behaviour and inhibition of chemoreceptor organs. Low levels of detergents may also increase the uptake of other pollutants. Invertebrates, especially in their juvenile stages, are extremely sensitive to detergents: concentrations below 0.1 mg/l interfere with growth and development in some species. The interactions between detergents and proteins, and their influence on membrane permeability may be the basis of the biological action of detergents. Detergents in natural waters are usually partially degraded, and a maximum permissible concentration of 0.5 mg/l would probably be harmless under most conditions. (AA)

2. Abeliovich, A. 1980. Factors Limiting Algal Growth in High-rate Oxidation Ponds. In: Proc. Int. Symp. Prod. and Use of Alga Biomass. Shelef and Soeder (Eds.) Elsevier, Amsterdam.

3. Adriano, D. C., L. T. Novak, A. E. Erickson, A. R. Wolcott, and B. G. Ellis. 1975. Effect of Long Term Land Disposal by Spray Irrigation of Food Processing Wastes on Some Chemical Properties of the Soil and Subsurface Waters. J. Environ. Qual. 4:244-248.

Food processing waste waters at two irrigated land disposal sites and subsurface waters (perched and ground waters) were monitored at daily to monthly intervals over one annual cycle of production. Soil profiles were sampled to depths up to 6.6m in the early fall.

Yearly inputs were calculated at 487 kg/ha total N (Kjeldahl plus NO_3-N) and 101 kg/ha soluble PO_4-P (orthophosphate) from cannery wastes at site 1. Estimates for milk wastes at site 2 were 562 kg/ha total N and 522 kg/ha PO_4-P.

The range for NO_3-N in subsurface waters was 7 to 16 ppm at site 1 (perched water at 1.5m) and 2 to 41 ppm at site 2 (ground water at 0.9 m). Maximum concentrations, found in summer, were essentially the same as the average for total N in the input wastes (16 ppm at site 1 and 38 ppm at site 2). Nitrate was stable in the percolation stream below the root zone. Annual additions to subsurface waters were estimated at 76% of input N at site 1 and 65% at site 2.

The range of PO_4-P in subsurface waters was 0.5 to 1.5 ppm at site 1 and 0.04 to 1.8 ppm at site 2; average waste water concentrations were 3 and 35 ppm. The highest concentrations in subsurface water were found in spring. Annual subsurface discharge was estimated at 27% of input P at site 1 and 2% at site 2. The extensive removals of PO_4 and the similar concentrations encountered in subsurface waters are of theoretical and practical interest since PO_4-P had already accumulated in soil profiles at both sites in quantities which exceed the Langmuir maxima for nonirrigated control soils.

During seasons of major irrigation input, NO_3 appeared in subsurface waters in concentrations exceeding public health standards; PO_4 concentrations exceeded environmental guidelines at all times except where irrigation was discontinued during the winter at site 2.

Soil systems appeared poised to discharge at the observed rates because of the large quantities of organic N and fixed P which had accumulated in the profiles over 20 years operation at site 1 and 10 years at site 2. The rate of residual accumulation in soil could have been reduced by harvest to extend system life materially. The harvest potential of three grass clippings per season removed for silage was estimated experimentally at 31% of input N at both sites, 80% of input PO_4 at site 1 and 27% at site 2. (AA)

4. Akin, E. W., et al. 1971. Enteric Viruses in Ground and Surface Waters: a Review of their Occurrence and Survival, pp. 59-74. In V. Snoeyink and V. Griffin (eds.), Virus and Water Quality: Occurrence and Control. Univ. of Illinois, Urbana-Champaign.

5. Alabaster, J. S. 1959. Effect of Sewage Effluent on Distribution of Dissolved Oxygen and Fish in a Stream. J. Anim. Ecol., 28:283- .

6. Albrecht, S. C., and B. J. Barfield. 1981. Use of a Vegetative Filter Zone to Control Fine-Grained Sediments from Surface Mines. EPA 600/57-81-117. U.S. Environmental Protection Agency. Industrial Environmental Research Laboratory. Cincinnati, OH.

The objective of this study was "to demonstrate the effectiveness of a vegetative filter zone in trapping fine-grained sediments from surface mining operations." The area selected for study was located in Whitley County, Kentucky, directly below an active surface mining operation. The outslope above the filter was the primary drainage area monitored during this study.

Results of the monitoring efforts revealed that a dramatic reduction in sediment load was achieved by vegetative filtration for particle sizes larger than clay. Based on the results of this study, it was concluded that vegetatative filters are an effective control for reducing the quantity of sediment transported into surface streams and rivers from disturbed mined lands.

7. Alleman, J. E., and S. P. Lo. 1980. Investigation of Full-Scale Biological Batch Treatment of Intermittent Wastewater Flows. Tech. Rept. No 63. Water Resources Research Center. Univ. pf Maryland, College Park. 30 pp.

8. Allen, G., G. Conversano, and B. Colwell. 1972. A Pilot Fish-Pond System for Utilization of Sewage Effluents, Humboldt Bay, Northern California. California State Univ., Humboldt, Arcata. Marine Advisory Extension Service. 31 pp.

The paper documents all out-of-pocket and other real costs in the construction of a pilot fish pond system for the utilization of sewage effluents, Humboldt Bay, Northern California. Discussions deal with the engineering and construction problems encountered. A description of the project site and reasons for site selection are explained. (NT)

9. Allen, G. H. 1969. A Preliminary Bibliography on the Utilization of Sewage in Fish Culture. FAO Fisheries Circ. #308. Rome.

10. Allen, G. H. 1972. The Constructive Use of Sewage, with Particular Reference to Fish Culture. Marine Pollution and Sea Life. 506-513.

Giving a bibliography of 132 references, the author reviews methods for using sewage in aquaculture, particularly in fish culture, as in Germany, U.S.A., Israel, and India, and discusses the possibility of future world-wide developments, including the desirability of international co-operation for research on the use of waste waters in integrated agriculture aquaculture systems. (AS)

11. Allen, G. H. 1976. Rearing Pacific Salmon in Saltwater Ponds Fertilized with Domestic Wastewater. Sept. 1974-Nov. 1975 Data Rept. HSU-SG-10, Humboldt State Univ., Arcata, CA. 92 pp.

12. Allen, G. H., and R. A. Gearheart. 1978. Arcata Integrated Wastewater Treatment, Reclamation, and Salmon Ranching Project. California State Univ., Humboldt, Arcata. Marine Advisory Extension Service. NOAA, Office of Sea Grant. 76 pp.

13. Allen, G. H., and B. Hepher. 1976. Recycling of Wastes Through Aquaculture and Constraints to Wider Application. FAO Tech. Conf. on Aquaculture. Kyoto, Japan.

Pacific salmon smolts have been reared in saline ponds fertilized with domestic wastewaters. An artificial homestream is to be created from the discharge of a marsh-lake system to be developed with reclaimed wastewater. This proposed salmon ranching method has the potential for producing food cheaply. (NT)

14. Allen, J. and S. S. Wilson. 1977. A Bibliography of References to Avian Botulism. U.S. Fish and Wildlife Service Special Scientific Report - Wildlife No. 24. Department of the Interior, Washington, DC. 6 pp.

15. Allen, M. B. 1955. General Features of Algal Growth in Sewage Oxidation Ponds. Calif. State Water Poll. Control Bd. Publ. #13.

16. Allison, J., and J. L. Fox. 1976. Coliform Monitoring of Waters Associated with the Cypress Dome Project, pp. 279-290. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

17. Althaus, H. 1966. Biological Wastewater Treatment with Bulrushes. G.W.F. 107(18):486-488.

18. American Water Works Association Research Foundation. 1979a. Proceedings of the Water Reuse Symposium. Volume 1. Held 25-30 March in Washington, DC. Co-sponsored with U.S. Department of the Interior, Office of Water Research and Technology; U.S. Environmental Protection Agency; National Science Foundation; and Water Pollution Control Federation. Denver, CO. 782 pp.

19. American Water Works Association Research Foundation. 1979b. Proceedings of the Water Reuse Symposium. Volume 2. Held 25-30 March in Washington, DC. Co-sponsored with U.S. Department of the Interior, Office of Water Research and Technology; U.S. Environmental Protection Agency; National Science Foundation; and Water Pollution Control Federation. Denver, CO. 332 pp.

20. American Water Works Association Research Foundation. 1979c. Proceedings of the Water Reuse Symposium. Volume 3. Held 25-30 March in Washington, DC. Co-sponsored with U.S. Department of the Interior, Office of Water Research and Technology; U.S. Environmental Protection Agency; National Science Foundation; and Water Pollution Control Federation. Denver, CO. 1626 pp.

21. Anderson, R. K., and D. Kent. 1979. Progress Report: Drummond, Wisconsin, Tertiary Treatment Demonstration Project Study. Report to the U.S. Fish and Wildlife Service. University of Wisconsin, Stevens Point, WI. 22 pp.

The Drummond, Wisconsin wastewater treatment facility consists of a primary and two secondary reservoirs. Secondary effluent is spread on the surface of a nearby bog by means of a gated irrigation pipe. Theoretically, the receiving bog will provide tertiary treatment to the effluent without deleterious effects to the ecosystem. The initial discharge of effluent occurred on June 15, 1979.

The study area is a 25-acre sphagnum bog in sections 28 and 33, T45N, R7W, Bayfield County, Wisconsin, which drains into a 4.1-acre bog lake (Weso Lake) and thence to the Long Lake Branch of the White River. The objective of this study is to determine the effects of the secondary effluent on the fauna of the receiving bog.

22. Anon. 1970. Studies of Marine Estuarine Ecosystems Developing with Treated Sewage Wastes. University of North Carolina, Institute of Marine Sciences Annual Report for 1969-1970. NTIS No. PB-199 537. May. 364 p.

This is the second annual report in a study of ecological systems that develop when treated wastes from municipal sewage systems that develop when treated wastes from municipal sewage systems flow into estuarine waters. Studies by a team of faculty and students considered a small marsh-lined estuary, Calico Creek, which received wastes following secondary treatment, and a set of three ponds in which estuarine water and treated sewage mixture flows. Three control ponds received tapwater and estuarine water. In their second year, the ponds were rich in productivity with successive algal blooms throughout the year and a food chain culminating in blue crabs. Chapters are included on the events in the salinity regime and input management. Photosynthetic productivity and respiration, algal growth, phosphorous and nitrogen, bacteria, and animal populations. The presence of a substantial ecological system suggests a viable intermediary system interface is possible between man's municipal wastes and normal estuaries. These systems have potential for aquiculture and waste amelioration.

23. Anon. 1972. Outdoor Mass Culture of Marine Phyto-plankton. Aquaculture 1(2):181.

24. Anon. 1975a. Floating Aquatic Plants Remove Chemicals from Polluted Waters. Water and Pollution Control, 113(6): 23-25.

NASA's National Space Technology Laboratories (NSTL) in Bay St. Louis, Mississippi has been experimenting with water hyacinths to determine the plant's ability to absorb and concentrate toxic metals, and metabolize other chemical pollutants - phenols, creosols, insecticides, nitrates, and phosphates. In early 1975 large quantities of water hyacinths were planted in a portion of the 60-acre lagoon that serves as the city's total sewage disposal outlet. The planting begins a complex process that results in the total recycling of enormous quantities of water hyacinths. One month after initial stocking, plant harvesting begins; by this time the plants will have reproduced enough to appreciably reduce pollution levels. The harvested crop is subjected to procedures to determine impurity assimilation. Two methods under study by NSTL involve continual processing of the water hyacinths. Anaerobic fermentation converts shredded water hyacinths into bio-gas, similar to natural gas. The potential yield is expected to be 28,500 cubic meters of gas per acre of plants. Pyrolytic decomposition produces a mixed hydrocarbon fuel similar to biogas. Plants grown in domestic sewage effluent (low in toxic metal content) will be evaluated as an animal food source. Residues from these processes will yield high grade fertilizer. The advantages of the integrated aquatic plant disposal method are durability and low installation and maintenance costs. An obvious drawback is that it is limited to tropical and subtropical climate zones.

25. Anon. 1975b. Marshes and Wetlands May Provide Safe Community Tertiary Sewage Treatment. Compost Science, 16(4):31.

The preliminary conclusion of a University of Michigan Research Project now in its third year is that marshes, bogs, swamps and other wetlands are able to provide high-quality tertiary sewage treatment. The project was designed to find out whether the natural processes in a 1,000 acre marsh near Houghton Lake in North Central Lower Michigan will be able to provide tertiary balance. The research has included a survey of pertinent scientific literature, the construction of a computer model of the marsh, and small, carefully controlled, on-site experiments. The model portrays the dynamic character of the marsh and accurately simulates the complex interactions among soil, water, wildlife, and climate. The model predicts that when millions of gallons of secondarily treated effluent are pumped into the marsh, the four-foot layer of peatland covering the area will absorb many of the dissolved nutrients in the water; only a small portion of the total will be utilized by vegetation. Wetlands bordering lakes and streams must not be used for treatment because of the risk that effluent would reach adjacent waters before being sufficiently purified. Each potential treatment site must be thoroughly studied to ensure that the wetland will be able to remain in an aesthetic and viable state, and the water quality will meet environmental standards.

26. Anon. 1977a. Concept, Research, Approval...An Effluent Irrigation Project Houghton Lake Sewer Authority. Consulting Engineer. 48(5):77.

A marshland irrigation system was proposed for the disposal of treatment plant effluents in Michigan. Two possible advantages were seen: an estimated cost savings of $700,000 over the use of a conventional irrigation system, and improved food supply and wildlife proliferation in the marsh area. Because of the lack of data on wetlands irrigation in Michigan, a test program was conducted before project approval. The test area was evaluated through plant, soil, and insect samples and through water quality tests. The organic deposits proved excellent in nutrient removal without overloading, and no adverse effects were detected in the test program. The application of 12.5 million gallons of wastewater during 1975 and 1976 continued to produce favorable results without adverse effects. The marsh ecosystem was not damaged, and plants grew larger and greener. The irrigation project was accepted as financially and environmentally feasible.

27. Anon. 1977b. Lab to Test Bulrushes as Filters for Sewage. Water and Wastes Engineering 14(9):16. September 1977.

Environmental Quality Laboratory, Inc., a subsidiary of General Development Corporation, is investigating the use of bulrushes to create a low-cost, natural means of tertiary sewage treatment. In experiments at Port Charlotte, Florida, 6 inch bulrush plants were planted in plastic-lined troughs which were filled with water to create a half-acre artificial marsh. A 12-month testing program is being used to evaluate phosphorus and nitrogen removal from primary and secondary treated effluents by bulrushes in the waste water flooded artificial marsh. Since advanced waste water treatment is required for the future, the marshland filtration system may provide tertiary treatment at lower construction and maintenance costs than conventional systems.

28. Anon. 1977c. Using Wetlands for Wastewater Treatment. Journal Water Pollution Control Federation. 49(7):1581. July, 1977.

The possible use of wetlands in Michigan and Florida for final treatment of municipal wastewater has been considered. At a trial site in Florida, wastewater is pumped into cypress ponds where nutrients are absorbed by vegetation. Costs for this method of treatment are approximately 50 percent less than for treatment by a conventional plant. At a trial site in Michigan, wastewater is pumped into a peat marsh for the removal of nutrients.

29. Anon. 1979. Treatment of Stormwater Runoff by a Marsh/Flood Basin. Association of Bay Area Governments. Berkeley, CA.

The flood basin functions as a marsh/wetland. The first year's results of the study show that pickleweed dominates the lower elevation marsh areas that are subject to daily and seasonal inundation. Pickleweed also tends to concentrate heavy metals to a greater extent than the mixed marsh or upland grass vegetation. The aerial plant parts of pickleweed demonstrates the ability to concentrate heavy metals - particularly Zn and Cd - at significant levels beyond soil and stormwater concentrations.

30. Anon. 1980. Solar Aquaculture Wastewater Treatment Plant. Public Works (USA) 111(5):122.

The Solar Aquacell System of wastewater treatment which utilizes natural ecological processes in an anaerobic pond lined and covered with a rubber membrane, creating a sealed chamber. Here between 30-50 percent of solids are settled and digested. Secondary treatment is in an aerated pond from which waste water flows to an aerated lagoon covered with water hyacinths and duckweeds which metabolize wastewater nutrients. These ponds are enclosed in a solar-heated greenhouse. Effluent from the lagoons is passed through a sand filter into an ozone contact chamber for final disinfection.

31. Anthony, R. G., G. R. Bierei, and R. Kozlowski. 1978. Effects of Municipal Wastewater Irrigation on Select Species of Mammals, pp. 281-287. In H. L. McKim (coor.), State of Knowledge in Land Treatment of Wastewater. Vol. 2. Proceedings of an international symposium held 20-25 August 1978 at Hanover, NH, sponsored by U.S. Army Corps of Engineers.

32. Anthony, R. G., and G. W. Wood. 1979. Effects of Municipal Wastewater Irrigation on Wildlife and Wildlife Habitat, pp. 213-223. In W. E. Sopper and S. N. Kerr (eds.), Utilization of Municipal Sewage Effluent and Sludge on Forest and Disturbed Land. The Pennsylvania State University Press, University Park, PA.

The effects of wastewater renovation on wildlife and wildlife habitat have been investigated in mixed oak and aspen/pine/shrub habitats. Influence of wastewater on vegetation and wildlife is dependent on the type of habitat irrigated and the species of wildlife in question. Studies to date indicate no major detrimental effect of irrigation and wildlife and wildlife habitat; however, some influences are apparent. The establishment of lush herbaceous undergrowth in mixed oak habitats decreases forage production for white-tailed deer, results in higher populations of white-footed mice during the fall, and appears to reduce stability and abundance of songbird populations. The influences of wastewater irrigation in aspen/pine/shurb habitats on wildlife and wildlife habitat appear to be less negative. In these habitats the quantity and quality of forage production for white-tailed deer and cottontail rabbits may be increased.

Songbirds avoided irrigated sites while irrigation was in progress, but use of these areas was normal when irrigation was not in progress. Songbirds also used irrigated mixed oak habitats less during early summer but significantly more during late summer. Wastewater irrigation appeared to favor species of songbirds at the expense of diversity.

Heavy metals were not accumulating in cottontail rabbits or white-footed mice inhabiting irrigated sites. These studies should be continued over longer time periods and in areas where industrial wastes create higher risks concerning this hazard.

Studies on the effect of wastewater renovation on wildlife and wildlife habitat have been limited to only a few vegetative types and have been hindered by small plot size and short duration of investigations. As larger irrigation systems become operable, opportunities to investigate the definitive relationship between habitat changes and wildlife responses will arise. Integral to these studies are investigations on the enhancement, prevalence, and pathogenicity of disease in wildlife which may present a human health hazard. (AA)

33. Anthony, R.G. and R. Kozlowski. 1982. Heavy Metals in Tissues of Small Mammals Inhabiting Waste Water Irrigated Habitats. Journal of Environmental Qualities. 11:20-22.

Concentrations of heavy metals in liver and kidney of meadow voles (Microtus pennsylvanicus) and white-footed mice (Permyscus leucopus) from wastewater-irrigated and control areas were analyzed. Heavy metals were not accumulating in meadow voles inhabiting a reed canarygrass (Phalaris arundinacea) field irrigated with sewage effluent. In contrast, Pb and Cd concentrations were significantly higher in tissues of white-footed mice inhabiting an irrigated forested site as compared with a control forested site. However, concentrations of Pb and Cd were not high enough to be considered toxic. Cadmium/zinc ratios for kidneys of small mammals were higher than those for soils and vegetation on irrigated areas, demonstrating potentially hazardous levels in herbivorous small mammals inhabiting areas irrigated with sewage effluent at application rates ranging from 5.0 to 7.5 cm/week for 14 years. (AA)

34. Attwell, B.J. et al. 1980. The Uptake of Phosphate by Carex spp. from Oligotrophic to Eutrophic Swamp Habitats. Physiologia Plantarum 44(4):______________.

35. AveLallemant, S. P., and J. W. Held. 1980. Assessment of Sewage Lagoons as Potential Fish Culture Sites in West Central Wisconsin. University of Wisconsin-Madison. Water Resources Center. Office of Water Research and Technology, Washington, DC. 92 pp.

The potential of wastewater treatment lagoons in Wisconsin for culturing fathead minnows (Pimphales promelas) was considered. The efficacy of this treatment strategy in terms of improving effluent water quality by reclaiming nutrients in the form of fish biomass and reducing treatment costs by providing marketable bait fish was assessed.

Wastewater lagoon systems located in 19 counties in west-central Wisconsin were assessed as potential fish culture sites during 1978 and 1979. Decisions were based on field measurements of temperature and dissolved oxygen (DO), number of lagoons, loading rates, and 24-hr, on-site cage bioassays with fathead minnows. Water samples for chemical and phytoplankton analyses were collected every 2 weeks from May through September at 10 of the facilities during 1979.

Successful fish culture in wastewater treatment lagoons appears to depend on the loading rate and design capacity of the facilities considered. High levels of ammonia-nitrogen and low levels of DO were major limitations to fish culture in sewage lagoons. Characteristics of lagoon systems with a high probability of culture success include moderate loading rates, pretreatment of waste and aeration. Fish culture in wastewater lagoons may provide a harvestable by-product which could help offset operating costs. (AA)

36. AveLallemant, S. P. (In preparation). Baitfish Culture in Wastewater Treatment Lagoons in Wisconsin. Master's Thesis. Univ. of Wisconsin. La Crosse.

37. Azharia Jahn, Samia. 1976. Sudanese Native Methods for the Purification of Nile Water During the Flood Season. p. 95-106, *In*: Biological Control of Water Pollution. J. Tourbier and R.W. Pierson, Jr. (Editors). University of Pennsylvania Press.

38. Badour, S. S., H. R. Godavari, A. Hussain, Y. C. Tai, and E. R. Waygood. 1980. Purification and Reclamation of Farm and Urban Wastes by *Euglena gracilis*: Photosynthetic Capacity, Effect of pH, Temperature, Acetate, and Whey. Environmental Pollution 23(3):179-215.

The purpose of this study was to provide an efficient, inexpensive algal system for the purification of urban and farm wastes, and the conversion of organic and inorganic nutrients into a mono-algal product that could be standardized as a feedstuff or as a fertilizer, with the remaining water fit for aquaculture or human consumption. The method and results are described in detail. The system proposed could be useful for purifying and reclaiming wastes by *Euglena gracilis*, especially for the dairy and meat-packing industries, and in increasing the organic matter of laterite soils, provided that wastes are readily accessible. (AL)

39. Bagnall, L. O. 1979. Resource Recovery from Wastewater Aquaculture, pp. 421-439. *In* R. K. Bastian and R. C. Reed (Project Officers), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA-430/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division, Washington, DC. 485 pp.

Removal and recycling of the nutrients and other components in the wastewater aquaculture system are completed by harvesting, processing and utilizing the aquatic organisms in which the nutrients are collected. Aquatic species grown in wastewater have been experimentally used for food, feed, fiber, fertilizer and energy. Some of the processes and products appear to be technologically and economically feasible on an operational scale.

40. Bagnell, L.O. et al. 1974. Feed and Fiber from Effluent-Grown Water Hyacinth, pp. 116-141. *In*: Wastewater Use in the Production of Food and Fiber-Proc. U.S. Environmental Protection Agency, Ada, OK.

41. Bajer, D.C. and W.B. Fryer. 1973. Undesirable Plant Response With Sewage Irrigation. J. Irr. Drain. Div. Am. Soc. Civil Eng. 99:133-141.

42. Ball, R.C. 1977. The Michigan State University Management Project--A Facility for Research in Recycling Treated Wastewater. p.205-256. In: F.M. D'Itri (ed.) Wastewater Renovation and Reuse. Marcei Dekker, Inc., New York

43. Baker, F.C. 1910. The Ecology of the Skokie Marsh Area, with Special Reference to the Mollusca. Bulletin of the Illinois State Laboratory of Natural History 8(4):441-499.

44. Banus, M.D., I. Valiela, and J.M. Teal. 1975. Lead, Zinc, and Cadmium Budgets in Experimentally Enriched Salt Marsh Ecosystems. Estuarine and Coastal Marine Science 3:421-430

The amounts of lead, zinc and cadmium were measured in various components of a salt-marsh ecosystem experimentally treated at two levels with a metals-containing fertilizer. Lead entering a salt marsh is largely retained by the surface sediments but 6-8% is taken up by marsh grasses. Lead in grass tops is exported as detritus to deeper waters but this loss was only about 3-4% of the entering lead. About 2% of the zinc at both levels of addition was exported in grass detritus while 16 and 45% were lost by undetermined mechanisms. About 80% of 15 mg m^{-2} $year^{-1}$ of cadmium added was retained in the sediments but at a dosage of 43 mg m^{-2} $year^{-1}$, 65% of the added cadmium left the plot, probably in dissolved form. The nitrogen added in conjunction with the metals resulted in increased movement of these metals into coastal waters due to increased production of grasses and increased metals contents of the grass tops. (AA)

45. Bardach, J.E., J.H. Ryther, and W.O. McLarney. 1972. Aquaculture, the Farming and Husbandry of Freshwater and Marine Organisms. John Wiley & Sons, Inc., New York. 868 pp.

1066. Barton, J.M. 1983.

46. Barth, C.L., and J.H. Bond. 1975. Water Management in Livestock Waste Handling Systems. Clemson Univ., SC. Water Resources Research Inst. Office of Water Research and Technology, Washington, DC.

The potential for minimizing the use of water in several animal waste treatment and storage procedures was evaluated. Laboratory units simulated the operation of aerobic lagoons, anaerobic lagoons, and storage for diluted swine feeding floor waste under conditions of controlled temperature, lighting, loading rate, and detention time. Anaerobic lagoon simulators achieved volatile solids (VS) reduction rates of 75.8% at 24°C and 200 days detention time and as little as 22.1% at 10°C and 100 days detention time. Degradation of VS was generally high in the loading rate range of 50 to 400 g VS/day/cu m and sludge storage efficiency was also high in that range. Liquefaction was a significant factor in the storage simulators with reductions of total solids by as much as 69%. Survival of the swine pathogens Salmonella cholerae-suis and Salmonella typhimurium in laboratory simulators of swine manure lagoons was determined and compared with the survival of the indicator organism Escherichia coli and fecal coliforms. The heaviest populations of the pathogens died off in 33 days. A cause of Salmonella die-off was proposed. A mathematical model was developed to describe the operation of the anaerobic animal waste lagoon and compared with relevant data which characterized the lagoon simulators. (NT)

47. Barret, G.W., G.M. Van Dyne, and E.P. Odum. 1976. Stress Ecology. Bio-Sciences 26(3):192-194.

48. Bartlett, M. S., L. C. Brown, N. B. Hanes, and N. H. Nickerson. 1979. Denitrification in fresh water wetland soil. J. Environ. Qual. 8(4): 460-464.

The application of secondary treated wastewater to freshwater wetlands received recent attention as a tertiary treatment method. The fate of nitrate nitrogen in such applications is of concern because of the potential for leaching into ground and surface water supplies. Nitrate removal in wetland soilwater suspensions was studied using a Warburg respirometer. All important pathways of nitrate reduction were accounted for using a N mass balance. Of the nitrate, 90-95% added to wetland soil-water suspensions is reduced to nitrogenous gases, with little or no transfer of nitrate to ammonia or organic nitrogen fractions. (BA)

49. Bartsch, A. F. 1956. Biological and chemical aspects of organic waste lagoons, pp. 61-86. In Land Disposal of Liquid Waste. Robert A. Taft Sanitary Engineering Center, Cincinnati, OH.

Growing popularity of waste stabilization ponds has created new interest in the pond mechanism and factors affecting it. Mode of action and impact of these factors influence design and resulting pond accomplishment. Of importance are photosynthetic oxygenation; interrelation of light penetration, algal density, and depth; the effect of temperature upon BOD rate, DO saturation level, and photosynthesis; and the manner in which seasonal forces are superimposed upon daily fluctuation in pond characteristics. The relative influence of ice cover and loading pattern and the responses that follow are pointed out. (AA)

50. Bastian, R.K. 1979. EPA Interest in the Potential for Wetland Treatment of Wastewater. In: Sutherland and Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a Conference held July 10-12 at Higgins Lake, MI.

Wetland treatment systems do appear to have a place as an alternative to conventional technologies used in municipal wastewater treatment. This is especially true for small communities faced with upgrading existing facilities and increasing wastewater treatment requirements.

Natural wetlands have inadvertently served as natural waste treatment systems for centuries. However, in recent years marshes, swamps, bogs, and other wetland areas have been successfully utilized as managed "nutrient sinks" for polishing partially treated effluents under relatively controlled conditions. Constructed wetlands have also been investigated and designed to meet specific project conditions while providing new wetland areas that also improve available wildlife habitats and provide the other numerous benefits of wetland areas.

Caution should be taken, however, to avoid negative public, governmental and/or scientist reactions that may be raised when proposing wetland treatment systems. The potential for impacting biotic communities, especially when involving natural wetlands in wastewater management, must be recognized and appropriate management practices and adequate monitoring implemented to avoid potential ecological problems from developing. After all, the overloading of our Nation's waterways with the wastes of civilization has been the major environmental reason for constructing and operating publicly owned wastewater treatment works in the first place.

The recent research and project development work that has been undertaken in Michigan, Florida, New York, California, and other areas on wetland treatment systems has helped draw more attention to the potential utility of these low cost and low energy consuming approaches for wastewater treatment. Such natural biological treatment systems should become increasingly important to EPA and local communities in developing the best practicable systems to meet future site specific wastewater treatment (and water reclamation) requirements. The future of wetland systems as an innovative/alternative technology for municipal wastewater treatment should be a bright one, although it could be greatly influenced by public opinion as well as concerns expressed by governmental officials and scientists which has certainly been true in the past for the acceptance of various "land treatment" technologies. (AA)

51. Bastian, R.K. 1981. EPA's Role and Interest in Using Wetlands for Wastewater Treatment, pp. 325-336. In: B. Richardson (ed.). Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

Wetland treatment systems involving natural or artificial wetlands appear to be very promising as a low cost, energy efficient alternative to certain conventional technologies used in municipal wastewater treatment. This is especially true for small communities faced with upgrading or expanding existing treatment facilties.

Both freshwater and saltwater wetlands have inadvertently served as natural waste treatment systems for centuries. However, in recent years a number of marshes, swamps, bogs, and other wetland areas in various parts of the country have been effectively utilized as managed natural biological systems to assist in wastewater treatment. Artificial wetlands also have been created and managed to meet specific pollution control requirements in an environmentally acceptable, cost-effective and energy efficient manner while effectively recycling the nutrients, organic matter and other wastewater constituents, improving available wildlife habitat, stabilizing stream flows, recharging ground water, etc. Therefore, such managed wetland wastewater treatment systems represent a logical extension of the basic land treatment recycle/reuse concepts which have been strongly encouraged by the Congress and EPA.

At the same time, the potential for wastewater treatment projects to harm biotic communities in existing wetlands must be recognized. Past incidents, where wetlands were used as a handy place to dispose of wastes and resulted in serious environmental problems, have produced strong responses from environmental groups, government agencies, and members of the scientific community. Their concerns and reactions have lead to a basic desire to protect existing wetlands from all outside influences. The need for wetland preservation should be addressed whenever wetlands wastewater treatment systems are proposed. These concerns and the ecological characteristics of wetlands suggest that appropriate management practices and adequate monitoring, as well as proper regulation and control of projects using wetlands for wastewater treatment, must be developed and implemented to avoid potential ecological problems or serious project opposition from developing.

1067. Bastian, R.K. and J. Benforado. 1983.

52. Bastian, R. K., and R. C. Reed (Project Officers). 1979. Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA-430/9-80-006. U. S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division, Washington, DC. 485 pp.

This publication contains an engineering assessment and the proceedings of a seminar held at the University of California-Davis on 11-12 September 1979, on the use of aquatic systems for the treatment of municipal wastewater. Case studies drawn from throughout the United States are used to illustrate the engineering, design, operation, and management of various wastewater aquaculture systems, including projects involving wetlands processes, aquatic plant processes, and combined aquatic processes. The potential recovery of energy and resources also is considered. (AA)

53. Bayley, S. E., J. Zoltek, Jr., and F. L. Boyt. 1975. Removal of Nutrients from Treated Municipal Wastewater by Wetland Vegetation. Final report to the City of Wildwood, Florida. Project No. 245-N34. Department of Environmental Engineering Sciences, Univ. of Florida, Gainesville, in cooperation with Michaels-Stiggins Incorporated, Orland, FL. 51 pp. plus appendices.

54. Bayley, S.E. 1983. The Effect of Natural Hydroperiod Fluctuations on Fresh Water Wetlands Receiving Added Nutrients. (Draft Manuscript). In: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters, Proceedings of a Workshop, June 23-25, 1982, University of Massachusetts, Amherst MA. US Fish and Wildlife Service and US Environmental Protection Agency.

55. Bedinger, M.S. 1978. Relation Between Forest Species and Flooding. p. 427-435, In: Greeson, P.E., J.R. Clark, and J.E. Clark (Editors), Wetland Functions and Values: the State of Our Understanding. American Water Resources Association, Minneapolis, MN.

56. Beeftink, W.G. 1977. Salt Marshes. pp. 93-121. In: R.S.K. Barnes (ed.) The Coastline. John Wiley and Sons, New York.

In temperate regions, salt marshes are found in and around river mouths, bays, Wadden areas, lagoons, and on coastal plains protected by sand- and shingle-spits. During marsh genesis, sedimentation of clay and silt takes place especially in the basins while coarser particles are deposited on the creek banks. The most common marsh use is grazing--usually by sheep, cows, and horses. Although mostly limited to the higher marshes and coastal dune-slacks, grazing may take up vast areas. Grazing includes selective cutting and removal of plant parts, local manuring, and trampling of the vegetation. The latter also leads to compaction of the topsoil, and, more intensified, to destruction of the turf-layer. Drainage of marshes is also another form of land reclamation. It results in a lowering of the water table and thus in changes in habitat, flora, and fauna. Transversing with ditches is harmful to the geomorphological development, for the natural watercourses may lose their function. Embankment is one of the most serious impacts on salt marshes. In industrialilzed areas, marshes are threatened by a complex array of man-made detritus, litter, and chemical substances derived from agricultural wastes, fertilizer or trash and urban sewage.

57. Beeston, M. D. 1971. Decapod Crustacean and Fish Populations in Experimental Marine Ponds Receiving Treated Sewage Wastes. Univ. of North Carolina, Inst. of Marine Sciences, Chapel Hill.

58. Bender, M. E., and D. L. Correll. 1974. The Use of Wetlands as Nutrient Removal Systems, Chesapeake Research Consortium Pub. No. 29. Univ. of Maryland, College Park.

Two different methodologies were used to investigate the effectiveness of marshes as nutrient removal systems in Chesapeake Bay. The first method employed fertilization or loading experiments in combination with tracers, while the second measured natural flux at two undisturbed study sites. Results showed that regularly flooded tidal marshes should not be considered as sinks for nitrogen or phosphorus forms. Although incoming particulate nitrogen was transformed in the marsh and exported to the estuary as ammonia and dissolved organic nitrogen, there was little, if any, net loss of available nitrogen and phosphorus in the marsh. The highest exports of dissolved inorganic phosphorus and ammonia occurred during the summer. High irregularly flooded salt meadow hay (Spartina patens) marshes appear to have some capacity for phosphorus removal. However, it was estimated that a loading of 29,000 gallons of secondary sewage per day would saturate the capacity of an acre of high marsh in 45 days, and once loaded to the capacity the acre could not be expected to be reused for many years. It is concluded that utilization of marshes of any type as nutrient removal systems is highly questionable.

59. Bender, M. E., and D. L. Correll. 1974. The Use of Wetlands as Tertiary Treatment Systems. Report No. NSF-RA-E-74-033. National Technical Information Service publication PB-241002.

60. Beneman, J. R. et al. 1977. Cultivation on Sewage of Microalgae Harvestable by Microstrainers. Sanitary Eng. Res. Lab., University of California, Richmond, CA.

61. Beneman, J. R. et al. 1978. Large-scale Freshwater Microalgal Biomass Production for Fuel and Fertilizer. Sanitary Eng. Res. Lab., University of California, Richmond, CA.

62. Benforado, J. 1981. Ecological Considerations in Wetland Treatment of Municipal Wastewater, pop. 307-324. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

The use of natural and artificially created wetlands for wastewater discharge or treatment offers potential to reduce costs, conserve energy, and reclaim wastewater constituents, when compared with conventional "high technology" sewage treatment. Benefits can include preservation of open space, potential for wildlife enhancement, flow stabilization, and more. However, ecological problems should be identified early in the development of wetland/wastewater technology. Technical issues include: health concerns for both humans and wildlife (e.g., viral, bacterial, and other pathogenic organisms, ground and surface water contamination, nuisance insects); food chain effects of toxic substances (e.g. biomagnification of heavy metals and synthetic organic chemicals, effect of surfactants on invertebrate populations); adverse community changes (e.g. accelerated succession, eutrophication, species changes, etc.); effects on fish and wildlife values (e.g., shellfish contamination, botulism in waterfowl, effect of chlorine compounds on fish, beneficial effects such as habitat enhancement); effects on other wetland functions and values (e.g., flood control, aesthetics, recreation); and long-term changes (e.g. cumulative effects).

Developing a sound policy on the use of wetland treatment systems is vital. Management guidelines and water quality standards must be developed that will allow for treatment, yet protect wetland functions and values. Four areas of study -- engineering design constraints/impact pathways/ecological effects/management potential -- provide a framework for developing such a policy. It seems prudent at this time to limit the general application of wetland treatment technology to artificially constructed wetlands and (in appropriate circumstances) to highly degraded natural wetlands; in the latter case, the overall objective should be to restore and enhance the wetland. Management of natural wetlands should optimize a combination of wetland values, rather than maximize sewage treatment capability.

1068. Benforado, J. 1983.

63. Bennett, C.L. 1979. The Concerns of a Public Servant When Secondary Treated Effluent is Spread Across a Wetland. In: J.C. Sutherland and R.H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater, Abstracts of a Conference held July 10-12 at Higgins Lake, MI.

As an ecologist concerned with lifestyles, environmental stability, etc., I well realize the problem involved with disposal of human waste and a system of recycling is the solution we feel most appropriate, but until such a program is instituted it seems a likely prospect to put partially treated effluent onto peat lands or other forms of bogs, marshes, and possibly even some flood plains. These areas, by their nature, are usually highly productive in all forms of wildlife and are used at different times of the year and in varying degrees by both wildlife and people. Our concerns are (1) public health, of course (2) changes in both flora and fauna that may occur, (3) deleterious effects to either flora or fauna, (4) to what extent the area can absorb the high level nutrients for a given period of time, (5) the watersheds involved, (6) maintaining the areas open to public use and not have them restricted because of material coming through with the effluent, (7) assurances that products coming off from the marsh remain usable, able to be handled, or edible, and (8) assurances that after the areas are saturated and pumping has stopped on those areas that they are still usable by the public, productive, and operate in an ecosystem fashion. In other words, we're concerned about the effect on plants, animals, substrate, and people. Disposal of municipal waste and industrial waste is an immediate problem and needs to be resolved, but industrial waste should not be put on a marsh even under experimental conditions. For handling municipal wastewater, wetlands appear to be a possible partial solution, but research efforts must be maintained to assure us that we are not taking a shallow-sighted view and end up with an even larger problem. I get scared every time we push our environmental system another notch up the scale. The past track record usually ends up with, "We did it wrong and now we must pay." (AA)

64. Bently, E.M. 1969. The Effect of Marshes on Water Quality. Ph.D. Diss. University of Wisconsin, Madison.

65. Berg, G. 1966. Virus Transmission by the Water Vehicle. II. Virus Removal by Sewage Treatment Procedures. Health Library Science 2:90.

66. Bevis, F.B. 1979. Ecological Considerations in the Management of Wastewater-engendered Volunteer Wetlands. The Michigan Wetlands Conference, July 10-12, Higgins Lake, MI. 19 pp.

This is a collection of eighteen handouts used by Dr. Bevis in his presentation at the Michigan Wetlands Conference at Higgins Lake, Michigan. Data from the Vermontville, Paw Paw, and Kinross volunteer wetland treatment sites were compiled and compared in the tables and figures. (EPA)

The phenology, phytosociology, productivity, nutrient levels, and wildlife values of the Vermontville, Michigan, wastewater-engendered volunteer wetlands were measured for the period June 1978-June 1979. Results of this work are reported here as:

1) Seasonal growth and development of the dominant wetland species, Typha latifolia L. (Robust Cattail) and T. angustifolia L. (Narrow-Leaved Cattail),
2) Vegetation descriptions of eight (8) different volunteer community types occurring in the wetlands,
3) Biomass accumulation, potential above-ground plant harvest, and decomposition of the vegetation,
4) TKN and TP accumulation in the vegetation, potential removal of these nutrients from the system via standing crop harvest,
5) Wildlife populations and utilization of the wetlands.

Observations on the above features from the PawPaw, Michigan, wastewater/wetlands system support the results of the Vermontville project. (AA)

67. Bevis, F. B., and R. H. Kadlec. 1979. Effect of Long-Term Discharge of Wastewater on a Northern Michigan Wetland. In J. C. Sutherland and R. H. Kadlec (eds.), Wetlands Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI.

Apparently the effluent discharge from Kincheloe/Kinross Air Force Base, initiated in the late 1940's, has converted portions of a diverse acid/peat system to a more specific monoculture cattail marsh system. The degree of this ecological/habitat change in a sensitive peatland ecosystem is being documented by observations on the composition of the vegetation; plant community distribution patterns; successional changes in the vegetation; and flow paths of the wastewater traceable through the wetland by following the cattail component community assemblages evident in the peatland.

Mapping and phytosociological descriptions of the vegetation have been determined in the field. The extend (acreage) of the various plant communities and their pattern of occurrence in the peatland are being determined from 1939, 1952, 1964, 1969, 1974 and 1978 aerial photographs. The study of the progress (rate) of community conversion(s) over the 25 years from a diverse, species-rich natural peatland to the cattail monoculture should help to establish appropriate guidelines for the effective utilization of such wetlands in wastewater polishing. (AA)

68. Bierei, G. R., G. W. Wood, and R. G. Anthony. 1975. Population response and Heavy Metals Concentrations in Cottontail Rabbits and Small Mammals in Wastewater Irrigated Habitat, pp. 1-9. In G. W. Wood et al. (eds.), Faunal Response to Spray Irrigation of Chlorinated Sewage

Effluent. Institute for Research on Land and Water Resources Research Publication 87. The Pennsylvania State University, University Park, PA

69. Bingham, F. T., A. L. Page, R. J. Mahler, and T J. Ganje. 1975. Growth and Cadmium Accumulation of Plants Grown on a Soil Treated with a Cadmium-enriched Sewage Sludge. Toxicity. J. Environ. Qual. 4:207-211.

Corn, wheat, rice, field bean, soybean, spinach, lettuce, curlycress, carrot, turnip, radish, tomato, and squash plants were grown to commercial harvest stage using as the substrate, soil pretreated with a municipal sewage sludge (1%) containing variable amounts of $CdSO_4$ up to 640 ug Cd/g soil. Observations included injury symptoms, yield decrement, Cd level of diagnostic tissue, and Cd and Zn content of harvested produce. Cadmium sensitive plants such as spinach, soybean, curlycress, and lettuce were injured by soil Cd levels of 4-13 ug Cd/g soil; whereas, tomato and cabbage tolerated soil levels of approximately 170 ug Cd/g soil without exhibiting injury symptoms. Rice was tolerant at all levels tested. Leafy plants such as lettuce, spinach, and turnip greens (tops) accumulated 175 to 354 ug Cd/g; whereas, fruit and seed tissue of plants under comparable treatment, with the exception of soybean, accumulated no more than 10 to 15 ug Cd/g tissue. The concentrations for soybean extended up to 30 ug Cd/g tissue. Paddy rice exhibited no ill effects for soil Cd treatments up to 640 ug Cd/g soil. Grain of plants under the 640 ug Cd/g treatment contained 2 ug Cd/g tissue. DPTA-extractable Cd correlated (r=0.99) with the level of $CdSO_4$ added to the substrate. (AA)

70. Bingham, F. T., A.L. Page, R.J. Mahler, and T.J. Ganje. 1976. Cadmium Availability to Rice in Sludge-amended Soil Under "Flood" and "Non Flood" Culture. Soil Sci. Soc. Am. J. 40: 715-719.

Rice plants (*Oryza sativa* var. 'Colusa') were grown to maturity in pots containing a soil (Domino silt loam, pH 7.5, *Xerollilc calciorthid*) amended with 1% sewage sludge enriched with variable amounts of CdSO, ranging up to 640 ug Cd/g. Two sets of soil cultures were used, one for rice under continuous flood and the other under nonflood conditions. Grain production for rice under flood management was relatively unaffected by the Cd treatment; 25% yield decrement was associated with a treatment of 320 ug Cd/g. Under nonflood management, however, a comparable decrement in grain production was observed with a treatment of only 17 ug Cd/g. The Cd content of mature leaves at early flowering varied from approximately 0.3 ug Cd/g for the controls to 2.8 ug Cd/g for plants receiving the highest Cd treatments. Leaf Cd values were slightly higher under the nonflood culture. The Cd content of the grain under nonflood management was approximately 55% greater than than of grain under flood management. The Cd content of mature leaves correlated with grain production (r=0.872 **) for rice produced under either flood or nonflood culture. Chemical analysis of saturation extracts revealed greatly reduced Cd concentrations in soil solutions under flood management which may account for the greater tolerance of the cultivar to soil Cd under flood culture. This reduced availability of Cd in flooded soils is attributed to precipitation of CdS. (AA)

71. Bisogni, J. J., Jr., and A. W. Lawrence. 1975. Kinetics of Mercury Methylation in Aerobic and Anaerobic Aquatic Environments. Journal Water Pollution Control Federation 47:135-152.

The microbial transformation of inorganic mercury to organic mercury (monomethyl and dimethyl mercury) was studied under a variety of conditions. A kinetic model was proposed and experimentally verified to describe the rate of microbial methylation as a function of the followoing parameters: relative microbial activity; biochemical availability of inorganic mercury; total inorganic mercury concentration; and redox potential. The model and the experimental results demonstrated that mercury may be methylated under anaerobic and aerobic conditions and that the predominant methylation product near neutral pH is monomethyl mercury. It was also found that large amounts of inorganic mercury may be released from an aquatic system as volatile elemental mercury. Application of the kinetic model to natural aquatic benthic regions and biological wastewater treatment processes is discussed in terms of possible control of the methylation phenomenon. (AA)

72. Bitton, G., G. E. Gifford, C. Monteith, and O. Pancorbo. 1977. Virus Removal in Marine Aquaculture Systems. Revue Internationale d'Oceanographic Medicale 48:47-52.

The possibility of removing polioviruses from sea water, secondary sewage effluent and mixtures of the two was investigated using a magnetic separation process. The object was to remove poliovirus without reducing the nutrient content of the water-sewage mixture, and the growth of two types of marine diatom in the filtered effluent was tested. It was concluded that magnetic filtration could form an effective primary step for removal of viruses in an aquaculture system without affecting the subsequent growth of algae acting as primary producers in the aquatic system. (AL)

73. Bitton, G., and N. Masterson. 1975. Virus: Effect of Dome Water on the Movement of Poliovirus Type 1 and Bacteriophage T_2 through a Sandy Soil Sampled at Sewage Dome 1, pp. 383-384. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling and Conservation. Second Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

74. Bitton, G., P. R. Scheureman, G. E. Gifford, and A. R. Overman. 1976. Movement of Viruses through a Cypress Dome: Evaluation of the Virus-retention Capacity of the Dome Sediments and of a Loamy Sand Layer, pp. 321-335. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling and Conservation, Third Annual Report. Univ. of Florida, Gainesville.

1069. Black, S.A., I. Wile, and G. Miller. 1981.

75. Blumer, K. 1978. The Use of Wetlands for Treating Wastes - Wisdom in Diversity, pp. 182-201. In M. A. Drew (ed.), Environmental Quality Through Wetlands Utilization. Proceedings of a symposium held 28 February 2-March 1978, at Tallahassee, Florida. Sponsored by the Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin, Tallahassee, FL.

Two artificial wetland systems consisting of linear configurations of a marsh-pond and a meadow-marsh-pond have been treating sewage in continuous operation for four years. Data from the past two and one half years suggest that the trapping of nutrients may be increased by increasing the number of biotopes in the flow sequence.

For the entire system, the retention of phosphorus and nitrogen per unit area of wetland appears greater when a variety of ecocomponents are used in sequence than if only one type of system is used. By increasing the physical and biological barriers to nutrient movement, an increase in the number of habitats (and ecological niches) is achieved. This seems to be especially important when hydrologic flow alternates between drought and flood, and in a temperate climate with dramatic seasonal temperature differences.

The implication for the Kissimmee watershed, beset with the problems of high seasonal nutrient flushes, is that a management strategy which includes the intermittent use of diverse wetland ecosystems can be expected to achieve a greater degree of nutrient retention than a strategy which attemps to optimize a single type of ecosystem, for example a marsh alone. Practical applications may include such simple measures as providing ponds to alternate with marsh wetlands, or designing wetlands with island meadows in appropriate sequences. (AA)

76. Bogaert, R. M. Nocturnal Dissolved Oxygen and Ammonia Cycles in the Wastewater Fed Marshes of Mt. View Sanitary District. Presented at the Water Reuse Symposium II. Washington, DC. Aug. 23-28, 1981.

Mt. View Sanitary District has had a system of marshlands fed entirely by secondary treated wastewater since 1975. The creation, management, and development of the marshlands was reported by Francesca Demgen in 1979.

In 1979-1980, a special monitoring program was conducted at the request of the California Regional Water Quality Control Board, San Francisco Bay Region (CRWQCB). This program monitored several water quality parameters. These parameters were of concern because of their effects when the marsh waters are released from the marsh environment.

Nocturnal dissolved oxygen cycles were studied during the winter, summer, and early fall. There were five monitoring stations, one in each pond, at which D. O. concentrations were recorded through the night. Lowest levels averaged 4.0 mg/L in three ponds; these levels consistently occurred at about 8 am. Lowest D. O. levels of about 1.0 mg/L occurred in cattail choked pond and in the pond which first receives the wastewater.

Un-ionized ammonia levels were monitored for four weeks during the dry weather and for four weeks during the wet weather. Un-ionized ammonia levels averaged 0.22 mg/L at all stations during the winter monitoring. During the summer dry weather monitoring, un-ionized ammonia levels averaged 0.210 mg/L at one station, 0.026 mg/L at a second station, and 0.050 mg/L at a third. Transitory levels above the 0.4 mg/L maximum limit allowed in receiving waters occurred once at one station. Other stations occasionally reached 0.1 mg/L. The marshlands at present have two fish species, carp, and mosquito fish. Carp develop gill lesions when exposed to 0.1 mg/L un-ionized ammonia for periods exceeding 35 days.

Prime factor causing the high, transitory levels was algal photosynthesis. This activity increases the pH of the water; since un-ionized ammonia concentration increases with pH, concentration rose as the day progressed.

77. Bollman, F. H. 1975. The Value of Estuarine Fisheries Habitats: Some Basic Considerations in their Preservation. Proc. Conf. on Estuarine Pollution Control and Assessment. Pensacola, FL. 11-13 Feb. 1975. EPA report 7-77-007B/1-77-007A.

Two broad sources of degradation of fishery habitat are foreseen as resulting from population growth and economic development. These are direct pollution of nutrients and toxic materials, and secondly, physical alteration. Three areas of intensified use will increase the difficulty in maintaining fishery resources in the estuary. These include: 1) increased municipal and industrial waste loads, 2) leakage of petroleum and petroleum products into estuaries, 3) upstream activities affecting freshwater inflows. There is an urgent need to improve EIS's so that the full extent of the value is displayed for the decisionmakers. (WE)

78. Boto, K. G., and W. H. Patrick, Jr. 1979. Role of Wetlands in the Removal of Suspended Sediments, pp. 479-489. In P. E. Greeson, J. R. Clark, and J. E. Clark (eds.), Wetland Functions and Values: the State of Our Understanding. American Water Resources Association, Minneapolis, MN.

One of the major functions of wetlands is the removal of suspended sediment from water moving through the wetlands. Flow rate is decreased as the water moves more by sheet flow than by channel flow, and the resulting decrease in velocity and the presence of vegetation promote fallout of suspended particles. The effect of salt water in estuarine mixing is to further enhance sediment removal by flocculation of clay particles. Transfer of the suspended sediment and the associated dissolved materials from the water column to the land surface has important consequences both for the quality of the water and the properties and functions of the wetland. In areas where the land surface is subsiding, sediment removal from water is essential for maintaining the marsh surface. With increase in toxicant load of water reaching wetlands, they are serving more than in the past as a sink for materials of known toxic effects on biota. The long-term consequences of the effect are poorly understood and deserve study. (AA)

79. Bourg, A. C. M., I. Valiela, and J. M. Teal. 1979. Heavy metal budgets in salt marsh ecosystems. Presented at the Commission of European Communities et al. Heavy Metals in the Environment International Conf., London. Sept. 1979. 365 pp.

Research report: The consequences of enriching salt marshes with a sludge that contains fertilizer were examined. Marsh capacity to retain heavy metals present in the sludge was surveyed. The metal load of the sediment increased with application of the sludge fertilizer. The concentrations of cadmium, chromium, copper, and nickel in marsh plants were greater than those in control plants. Sediment cores showed a downward migration of metals. No deleterious effects of the metals on plants were observed. (EL)

80. Bourne, G. 1976. Water Quality Effects of Sewage Effluent on a Cypress Dome System. Master's thesis, Department of Environmental Engineering, University of Florida, Gainesville.

81. Bower, H., and R.L. Chaney, 1974. Land Treatment of Wastewater. Adv. Agron. 26:133-176

82. Boyd, C. E. 1970. Vascular Aquatic Plants for Mineral Nutrient Removal from Polluted Waters. Econ. Bot. 241:95-103.

83. Boyd, C. E. 1971. A Bibliography of Interest in the Utilization of Vascular Aquatic Plants. Econ. Bot. 25: 74-84.

84. Boyt, F. L. 1975. A mixed hardwood swamp as an alternative to tertiary wastewater treatment, pp. 749-750. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Second Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

85. Boyt, F. L., S. E. Bayley, and J. Zoltek, Jr. 1977. Removal of nutrients from treated municipal wastewater by wetland vegetation. J. Water Pollut. Control Fed. 49(5):789-799.

A mixed hardwood swamp in central Florida, U.S.A., which has been receiving secondarily treated domestic wastewater from Wildwood for 20 years, was examined to determine the effectiveness of the swamp in removing nutrients from wastewater. After flowing through the experimental swamp, the nutrient concentration of the water was less than the concentration of nutrients found in the control swamp and in Lake

Panasoffkee, the final receiving body. Water samples throughout the experimental and control swamp were examined for pathogenic bacteria. Wetlands may be used as an alternative to tertiary treatment especially to increase nutrient removal. (BA)

86. Bozko, L. et al. 1967. Biological ponds as the third stage of sewage treatment. Cas. Woda Sanit. 40:201-202.

87. Bradford, G. R., A. L. Page, L. J. Lund, and W. Olmstead. 1975. Trace Element Concentrations of Sewage Treatment Plant Effluents and Sludges: Their Interactions With Soils and Uptake by Plants. J. Environ. Qual. 4:123-127.

Metropolitan sewage sludges and effluents were characterized in relation to their total and water extractable trace elements, their reactions with soils, and their effects on plants. The total concentrations of trace elements in sludges and effluents were highly variable depending on the source and were often much higher than concentrations found in soils. Concentrations of Cu, Zn, Ni, Co, and Cd were consistently greater in the saturation extracts obtained from sludges than those obtained from a large sampling of California soils. The effects of irrigating bean, barley, and tomato plants in a greenhouse sand culture experiment with diluted saturation extracts of sludges from different sources were all adverse but variable depending on the sludge source. Leaf samples from treated plants frequently contained toxic levels of B and excessive levels of one or more of the following elements: Cu, Mo, Ni, Co, Pb, and Cd. (AA)

88. Breckenridge, R.P., L.S. Cahn, T.L. Thurow. 1981. Biological Treatments and Uses of Geothermal Water as Alternatives to Injection, Idaho National Engineering Laboratory. EE&G Idaho, Inc. Idaho Falls, ID.

Results of experiments demonstrate the ability of biological systems to thrive on and accumulate elements from the geothermal effluent. Additional benefits can also be realized from the reuse of this water for irrigation or creation of fish or wildlife habitat. Future studies are aimed at further quantifying the treatment capability and the biomass production potential of biological systems using geothermal water. By providing an environmentally sound alternative to injection or a way to improve fluid quality prior to injection, the competitive economic position of geothermal commercialization may be enhanced.

1070. Brennan, K.M. 1981.

89. Brennan, K.M. and C.G. Garra. 1981. Wastewater Discharges to Wetlands in Six Midwestern States, pp. 285-294. In B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

An inventory was conducted of wastewater treatment facilities that discharge to wetlands in the states of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. The following information was obtained for each of the 96 facilities identified: location, type of facility, type of wastewater treatment, operational date, number of years of discharge, acreage of wetland, and general description of wetland. Each wetland tentatively was classified according to the U.S. Fish and Wildlife Service classification system of Cowardin, *et al*. (1979).

The greatest number of discharges are to Palustrine emergent wetlands (principally cattail marshes). Fifteen of the discharges are to man-modified wetlands. Three wastewater treatment systems have been designed to include the use of a nearby wetland as a tertiary treatment site. Three volunteer wetlands (wetlands that formed as a consequence of a wastewater discharge) also were identified. No artificial wetland treatmlent system is in operation within the six-state area. (AA)

1071. Brennan, K.M., S.D. Bath and G.L. Seegert. In press.

90. Breteler, R.J., I. Valiela, and J.M. Teal, 1981. Bioavailability of Mercury in Several Northeastern U.S. *Spartina* Ecosystems. Estuarine, Coastal and Shelf Science 12(2):155-166.

Although considerable research has been done on the release of mercury from the sediments of salt marsh environments and on factors contributing to the mercury concentration of organisms, little attention has been given to the effect of the sediment itself on the availability of soil-bound mercury to biota.

91. Brightman, R.S. 1976. Benthic Macroinvertebrate Response to Secondarily Treated Sewage Effluent in North-Central Florida Cypress Domes. Master's Thesis, University of Florida, Gainesville. 112 pp.

92. Brightman, R., and J.L. Fox. 1976. Response of Benthic Invertebrate Populations to sewage Addition. *In* H.T. Odum, K.C. Ewel, J.W. Ordway, and M.K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida, Gainesville.

93. Brinson, M.M. 1977. Decomposition and Nutrient Exchange of Litter in an Alluvial Swamp Forest. Ecology 58:601-609.

94. Brinson, M.M. 1983. Management Potential for Nutrient Removal in Forested Wetlands. (Draft Manuscript). *In*: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop, June 23-25, 1982, University of Massachusetts, Amherst, MA. US Fish and Wildlife Service and US Environmental Protection Agency.

95. Brinson, M. M., H. D. Bradshaw, and E. S. Kane. 1981. Nitrogen Cycling and Assimilative Capacity of Nitrogen and Phosphorus by Riverine Wetland Forests. Rept. No. UNC-WRRI-81-76. North Carolina Resources Research Inst. Raleigh.

Labeled (15N) nitrate and ammonium were added to swamp surface water and their diffusion to the forest floor was followed. Of the original nitrate added, 46% remained in the surface water of Tar Swamp and 62% in Creeping Swamp after 2 days. Two days after ammonium treatments, corresponding levels were 79% and 81%. As indicated by the absence of recoverable 15N in sediments following nitrate treatments, diffusion of labeled nitrate to the forest floor resulted in its transformation to N_2O or N_2 by denitrification. Available nitrogen reserves in the sediments were depleted through ammonification and nitrification during annual drydown episodes, and the capacity for additional nitrogen assimilation by the sediments was renewed. An experiment was then conducted to determine the capacity of sediments for sustained nutrient assimilation by adding nitrate, ammonium, phosphate, and secondarily treated sewage effluent to surface water in separate chambers at weekly intervals for 46 weeks. (AA)

96. Brown, J. L., and R. S. Farnham. 1976. Use of Peat for Wastewater Filtration - Principles and Methods. Submitted for publication. Fifth Int. Peat Cong., Warsaw.

97. Brown, R. J. (ed.). 1978. Water Pollution in Estuaries and Coastal Zones, Volume 2: A Bibliography with Abstracts. NTIS/PS-78/1176. Springfield, VA. 252 pp.

98. Brown, S. 1978. A Comparison of Cypress Ecosystems and their Role in the Landscape of Florida. Ph.D. Dissertation, University of Florida, Gainesville.

99. Brungs, W.A., R.W. Carlson W.B. Horning II, J.H. McCormick, R.L. Spehar, and J.D. Yount. 1978. Effects of Pollution on Freshwater Fish. J. Water Pollut. Control Fed. 50(6):1582-1637.

100. Bryan, E.H., 1981. Recycling Projects Receive "Appropriate" NSF Support. Biocycle 22(1):47.

The term appropriate technology describes approaches to solving problems that do not require large investments of capital resources, and the National Science Foundation has been instructed by Congress to support appropriate technology. The innovative concept of using wetlands for waste water management is an example of an appropriate technology. The foundation supported a basic study to mathematically model the wetland ecosystem near the community of Houghton Lake in Michigan. Field verification of the ecosystem models followed. Then a pilot scale experiment was conducted to verify the ecosystem model's predictions of the effects that the placement of the secondary effluent from the area's waste water treatment plant would have on the wetland. Now, full scale experimentation is in progress at Houghton Lake. The community's savings over a 20-year period were estimated to be $1.2 million over land application, the next least-cost alternative. Other current research includes alternative methods and systems for curbside sorting of municipal solid wastes and a project to use wastes to help revegetate the areas damaged by the eruption of Mt. St. Helens.

101. Buck, D.H., J.B. Richard, and C.R. Rose. 1978. Utilization of Swine Manure in a Polyculture of Asian and North American Fishes. Trans. Amer. Fish. Soc. 107(1):216-222.

Chinese methods of fish culture were evaluated for potential use in animal waste management, pollution control, and the production of protein. Two ponds were stock with grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molotrix*), bighead carp (*Aristichthys nobilis*), carp (*Cyprinus carpio*), northern largemouth bass (*Micropterus salmoides salmoides*), channel catfish (*Ictalurus punctatus*), and the hybrid of bigmouth buffalo female (*Ictiobus cyprinellus*) and black buffalo male (*I. niger*). One pond (0.127 hectare) received the total wastes from five growing pigs (about 39 pigs/hectare of water area), the other pond (0.121 hectare) received the wastes from eight pigs (66 pigs/hectare). Two consecutive lots of pigs were fattened during the study. Over a fish-growing period of about 170 days (May to October 1975) the net increments in fish biomass were 2,971 kg/hectare in the 0.127-hectare pond and 3,834 kg/hectare in the 0.121-hectare pond. A beneficial influence by the fish on water quality was indicated by continuously adequate levels of dissolved oxygen, and final biochemical oxygen demands in the range of 8-12 mg/liter. (AA)

102. Buck, J. D. 1973. Ecological Evaluation of Multiuse Waters Receiving Primary Treatment Effluent Prior to a Major Flow Increase. University of Connecticut, Storrs. Inst. of Water Resources.

A chemical and biological study is described for a Connecticut estuary receiving 0.25-0.50 MGD of treated sewage effluent prior to construction of a secondary treatment plant with a projected flow of 5-6 MGD. An adjacent, unpolluted cove was used as a control. Three stations in each estuary were sampled bi-weekly from September 1970 to June 1972. Analyses included temperature, salinity, dissolved oxygen, BOD, nitrate, and phosphate. Counts were made of total bacteria, total and fecal coliforms, fecal streptococci, phytoplankton, and benthic invertebrates. (NT)

103. Buckley, E. H. Mitigation of Habitat Losses in the Estuary of the Hudson River: Suggested Goals for Long Term Management. Presented at the American Fisheries Society/et al. Mitigation Symposium, Fort Collins, July 16-20, 1979. 108 pp.

Survey report: A biological information base obtained during investigation of an estuarine ecosystem of the Hudson River, NY, is used to determine mitigation requirements for long-term management of the estuary. Habitat creation can be combined with recreational development along the river to foster greater productivity and balance of species among the higher trophic levels. (27 References). (EL)

104. Burk, J. P., P. Hosier, A. Lawry, A. Lenz, and A. Mesrobian. 1973. Partial Recovery of Vegetation in a Pollution-damaged Marsh. Project Completion Report. Water Resources Research Center, Univ. of Massachusetts. Amherst.

105. Burke, W. 1975. Fertilizer and Other Chemical Losses in Drainage Water from a Blanket Bog. Irish J. Agric. Res. 14:163-178.

106. Burnett, M. No Date. Cypress Growth Response in a Sewage-Enriched Cypress Pond, pp. 774-782. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

107. Buros, O. K. 1976. Wastewater Reclamation Project, St. Croix, U. S. Virgin Islands. Environmental Protection Agency, Cincinnati, OH.

108. Burton, T. M., D. L. King, R. C. Ball, and T. G. Bahr. 1979. Utilization of Natural Ecosystems for Wastewater Renovation. Institute of Water Research, Michigan State University, East Lansing, MI. 153 pp.

Michigan State University constructed on 200 ha (500 acres) of the main campus, a permanent facility for the experimental treatment, recycle, and reuse of municipal sewage plant effluents. The facility provides for the diversion of up to 7570 m^3/d (2 MGD) of secondary effluent from an activated sludge treatment plant. This waste flow is directed away from the receiving stream to an intensely managed aquatic and terrestrial nutrient recycling system. The facility consists of a portion of the East Lansing Wastewater Treatment Plant, a transmission line, four experimental lakes, and a spray irrigation site. A primary objective is to filter nutrients from the waste flow as it proceeds through the system by incorporating nutrients into harvestable biomass.

The system has been in operation with tertiary effluent for about 18 months. It will go on line with secondary effluent in 1976. Biological activity in the aquatic system has a major impact on water quality as evidenced by significantly reduced water concentrations of phosphorus, nitrogen, and inorganic carbon. Much of the nutrient flow is shunted into harvestable plant material both in the aquatic and terrestrial portions of the system. (AA)

109. Buikema, A. L., and E. F. Benfield. 1980. Effects of Pollution on Freshwater Invertebrates. J. Water Pollut. Control Fed. 52(6): 1670-1686.

110. Buikema, A.L., E.F. Benfield and B.R. Niederlehner. 1981. Effects of Pollution on Freshwater Invertebrates. J. of Water Pollut. Control Federation 53(6):1007-1014

111. Burk, C.J., Lauermann, S.D. and A.L. Mesrobian, 1976. The Spread of Several Introduced or Recently Invading Aquatic Plants in Western Massachusetts. Rhodora 78(816):727-767.

Changes in the distributional status of several recently introduced or invading vascular plant species have been observed during the present century. Water clover, *Marsilea quadrifolia L*. has become established since 1945 along two miles of the Mill River in Northampton, Massachusetts, and successfully invaded the Arcadia Wildlife Sanctuary marsh during a period of disturbance. Water-meal, *Wolffia columbiana* (Karst) unknown in the area prior to 1933, is now abundant in highly eutrophic lakes and impoundments which receive sewage effluents. Water chestnut, *Trapa natans L.* has reached pest densities in Upper and Lower Ponds on the Mount Holyoke College campus in South Hadley and has escaped to form a colony downstream in Stoney Brook. Cooter-grass, *Cabomba caroliniana* (Gray), first detected in Massachusetts in 1930, has spread to several other western Massachusetts sites and is the dominant submerged aquatic plant life in Lake Rohunta in Franklin and Worcester Counties. Each of these species occurs in sites affected by some form of habitat disruption; none is yet so widespread as to be regularly encountered in freshwater systems.

112. Burns, L.A. 1978. Productivity, Biomass, and Water Relations in a Florida Cypress Forest. Ph.D. Dissertation, University of North Carolina, Chapel Hill.

113. Burton, T.M. 1981. The Effects of Riverine Marshes on Water Quality, pp. 139-152. *In* B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

Riverine marshes affect water quality in a number of ways. These marshes usually receive water during floods as overflows from the river to the marsh. They act as water retention basins and slowly release this water back to the stream during periods of low flows. While the water is retained in the marsh, part of the sediment load is deposited due to reduced carrying capacity of the slow moving water and entrapment of sediments in marsh vegetation. Much of the phosphorus, heavy metals, and toxic organic materials in stream water is transported by sorption on suspended sediments, and these materials are deposited with the sediments. The flooded anaerobic soils of the marsh also promote losses of certain elements to the atmosphere due to such products of microbial metabolism as nitrogen gas formed by denitrification, hydrogen sulfide, methane, etc., as well as products of aerobic decomposition at the thin oxidized microlayer at the surface of the sediment. Nutrient uptake and release patterns by the plant communities play a very important role in determining water quality outputs of the marsh. Riverine marshes appear to be traps for most nutrients on an annual basis but can act as sources of nutrients under certain conditions or during seasons where plant nutrient uptake is low and decomposition is high. The processes affecting water quality in riverine marshes will be discussed and quantified whenever possible using literature values. Ongoing studies on the effects of a Michigan river-mouth marsh on water quality will be described. (AA)

114. Burton, T.M. and J.E. Hook, 1982. Oldfield and Grass Management Studies on the Water Quality Management Facility at Michigan State University, p. 107-133. In Land Treatment of Municipal Wastewater: Vegetation Selection and Management. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan.

115. Button, G., N. Morton and G.E. Gifford. 1976. Effect of a Secondary Treatment Effluent on Movement of Viruses through a Cypress Dome Soil. J. Env. Qual. 5(4):370-375.

116. Burton, T.M., and D.L. King. 1979. A Lake-land System for Recycling Municipal Wastewater, pp.68-75. In Proceedings of the 1979 National Conference on Environmental Engineering, sponsored by the American Society of Civil Engineers, held 9-11 July 1979 at San Francisco, CA.

117. Byers, G.L. 1971. Influence of Wetlands on Quantity and Quality of Stream Flow. Water Resources Center, Durham, NH.

118. Cairns, J., Jr. 1976. Estimating the Assimilative Capacity of Water Ecosystems. pp. 173-189. In: Sharma, R.K., J.P. Buffington, and J.T. McFadden (eds.), The Biological Significance of Environmental Impacts. NR-CONF-002. US Nuclear Regulatory Commission, Washington, DC.

119. Carlson, P. R., Jr. 1977. Nutrients, Hydrogen Sulfide and Dry Matter Production of Spartina alterniflora in Three Salt Marshes. Association of Southeastern Biologists Bulletin 24(2):41-42.

120. Carpenter, R. L., M. S. Coleman, and R. Jarman. 1975. Aquaculture as an Alternative Wastewater Treatment System. Okla. State Dept. of Health, Okla. City. In: Tourbier, J. and R.W. Pierson, Jr. (eds.). 1976. Biological Control of Water Pollution, Univ. of PA. Press, Philadelphia.

121. Carpenter, R. L., H. K. Malone, A. F. Roy, A. L. Mitchum, H. E. Beauchamp, and M. S. Coleman. 1974. The Evaluation of Microbial Pathogens in Sewage and Sewage Grown Fish, pp. 46-55. In: Wastewater Use in the Production of Food and Fiber-proc. Environmental Protection Agency. Ada, OK.

122. Carriker, N.E. and P.L. Brezonik. 1975. Heavy Metals, p. 372. In: H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

Treated wastewater from a trailer park near Gainesville, FL was introduced into a small cypress dome. Water flow generally was downward, but occasionally horizontal flow was observed. Elevated levels of heavy metals were found in the upper sediment layers. (EP)

123. Carriker, N. E. 1977. Heavy Metal Interactions with Natural Organics in Aquatic Environments. Doctoral Dissertation, Department of Environmental Engineering Sciences, University of Florida, Gainesville. 155 pp.

124. Carter, V., M.S. Sedinger, R.P. Novitzki, and W.O. Wien. 1978. Water Resources and Wetlands. pp. 344-376, In: P.E., J.R. Clark, and J.E. Clark (eds.), Wetland Functions and Values: The State of Our Under standing. American Water Resources Association, Minneapolis, MN.

125. Cederquist, N. 1977. Wastewater Reclamation and Reuse Pilot Demonstration Program for the Suisun Marsh. Progress Report, U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Water Quality Branch, Sacramento, CA.

126. Cederquist, N. 1979. Using Wastewater for Duck Club Management in the Suisun Marsh of California. In J. C. Sutherland and R. H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI.

The Bureau of Reclamation in cooperation with the City of Fairfield, the Solano Irrigation District, and federal and state agencies has been investigating the use of wastewater for wetland management since 1973. The goal of the study is to find any problems wastewater may cause and develop management alternatives for successfully using wastewater to assist in maintaining the brackish water characteristics of the Suisun Marsh. The initial study involved the use of secondary treated effluent from the City of Fairfield's Cordelia treatment plant on about 10 acres of marsh and agriculture land from 1975 through the spring of 1978. In 1977, a 5-year study was started, using nitrified, filtered wastewater from the new 10.35 mgd Fairfield-Suisun subregional waste treatment facility. The study involves extensive monitoring of three clubs, each with 100 to 120 acres of ponds and limited monitoring of one club with 350 acres of ponds.

During the first two years, one club used 100 percent wastewater, one used a mix of waste and slough water, and the third used slough water only as a control. The 350 acre club used varying amounts of slough and wastewater. Operation is according to the schedule recommended by the Solano County Mosquito Abatement District and the Soil Conservation service. Under this schedule, the waterfowl ponds are flooded from October 1 through May 30, then drained and dried from June 1 to September 30. From about January 20 to March 30, the ponds are drained and filled two to three times to leach salts from the soil. The summer dry season is for mosquito, cattail and tule control. (AA)

127. Cederquist, N. 1980. Suisun Marsh Management Study: Progress Report on the Feasibility of Using Wastewater for Duck Club Management. U.S. Department of the Interior, Water and Power Resources Service, Sacramento, CA. 45 pp.

128. Cederquist, N. W., and R. W. Martin. Reclamation and Reuse of Wastewater in the Suisan Marsh, California. Presented at the AWWA Research Foundation/et al. Water Reuse Symposium, Washington, DC. March 25-30, 1979. 685 pp.

Technical Report: The waste water reclamation and reuse pilot demonstration program for the Suisan Marsh, Calif., was initiated in 1972 with the objective of evaluating the feasibility of beneficial reuse and treatment of municipal wastewater with marsh management. Existing techniques of marsh management were employed to maintain a desirable waterfowl habitat and agricultural irrigation in the marsh, utilizing wastewater as a supply. It was found that algae ponds could be used most of the year to provide water storage and treatment and treatment of wastewaters for supply to the irrigation marsh ponds. No environmental problems in the irrigated marsh ponds were encountered. Wastewater was shown to be a satisfactory source of irrigation water for pasturelands. (32 graphs, 3 maps). (EL)

129. Chabreck, R. H. 1976. Management of Wetlands for Wildlife Habitat Improvement, pp. 227-233. In M. Wiley (ed.), Estuarine processes. Vol. 1. Uses, Stresses, and Adaptation to the Estuary. Academic Press, Inc., New York, NY.

130. Chalmers, A. G., E. B. Haines, and B. F. Sherr. 1976. Capacity of a *Spartina* Salt Marsh to Assimilate Nitrogen from Secondarily Treated Sewage. Environ. Resource Cent. Georgia Inst. Technology, Atlanta. Tech. Rept. ERC-0776. 88 pp.

Air-dried, pulverized secondarily treated sewage sludge was applied to duplicate 100 sq m plots in a short *Spartina* high marsh near Sapelo Island, Georgia, at a rate of 200 g sludge, or 4 g nitrogen per square meter every two weeks for 12 months. Monthly measurements were made of nitrogen pools in the marsh plants and soils in the experimental plots and in duplicate control plots in the high marsh and in a low marsh area. Potential denitrification rates were also analyzed for marsh soils in the study sites. (NT)

131. Chamie, J. P. M. 1976. The Effects of Simulated Sewage Effluent on Decomposition, Nutrient Status, and Litterfall in a Central Michigan Peatland. Ph.D. Diss. Univ. of Michigan, Ann Arbor.

A wet peatland near Houghton Lake in central Michigan was chosen to test the feasibility of using a natural wetland as a tertiary system for handling secondary sewage effluent. Nutrient solutions simulating secondary sewage effluent were applied weekly from May to September during 1973 and 1974 on an area dominated by sedge-willow and leatherleaf-bog birch cover types. Litter biomass in both types showed significant and direct responses in retention of elemental concentrations of N, P, K, Na, Ca, and Mg following weekly nutrient application. These values decreased over winter to approximately spring levels. No significant differences for any species due to water and/or nutrient treatment additions were detected for weight loss or nutrient concentrations of vegetation exposed to decomposition. Based on nutrient concentration and conditions used in this study, no significant changes are likely to occur in the amounts and rates of litter fall or decomposition of vegetation in the area studied. (WE)

132. Chan, E., T. A. Bursztynsky, N. Hantzsche, and Y. J. Litwin. 1981. The Use of Wetlands for Water Pollution Control. Municipal Environmental Research Lab. U. S. Environmental Protection Agency. Cincinnati, OH.

Wetlands such as marshes, swamps, and artificial wetlands, have been shown to remove selected pollutants from urban stormwater runoff and treated municipal wastewaters. Wetlands have produced reduction in BOD, pathogens, and some hydrocarbons, and excel in nitrogen removal. They have been reported to act as sinks for trace metals, phosphorus, and suspended solids. Physical pollutant removal mechanisms in wetlands include sedimentation, coagulation, chemical filtration, volatilization, adsorption, and chelation. Vegetative mechanisms include absorption through roots, stems and leaves, filtration and chemical transformations in the plants. Chemical transformations of some water borne pollutants also occur in sediment and the water column as a result of anaerobic or aerobic conditions, the presence of catalysts and reactive substances, and with the aid of microbial action. Although individual plant species have been studied for their pollutant removal properties, the interaction of numerous plant and animal species in pollutant removal in a wetland is not well understood.

133. Chaney, R. L., and P. T. Hundemann. 1979. Use of Peat Columns to Remove Cadmium from Wastewaters. J. Water Pollut. Control Fed. 51:17-21.

A method for reducing effluent Cd from industrial wastewaters to levels equal or below those normally found in domestic wastewaters was examined. A synthetic oxidized Cd plating solution (100 mg/l Cd) was adjusted to levels of pH and carbonate which would cause very low equilibrium dissolved Cd; 560 ug/l Cd remained soluble because of slow precipitation. The solution was added in 1 l increments (14 times) to 60 cm columns (4.9 cm ID) of peat or peat plus $CaCO_3$. Effluent Cd was measured for each 1 l addition. Cd in the peat columns was analyzed at various depths at the end of the leachings. Results showed that peat was both an excellent physical filter of Cd precipitates and also an effective material for dissolved Cd. Effluent averaged 2 ug/l Cd for peat columns and 24 ug/l Cd for peak plus $CaCO_3$. Column analysis showed that most of the CD was present in the upper few centimeters of the column. Thus peat appears to be an effective and inexpensive method for removing Cd from pH and carbonate adjusted industrial wastewaters free of strong chelating agents. (AA)

134. Chapel Hill Inst. of Marine Science. Structure and Functioning of Estuarine Ecosystems Exposed to Treated Sewage Wastes. North Carolina Univ. NTIS Com-71-00688, Springfield, VA.

135. Chatterjie, S. N., B. K. Arora, and D. R. Gupta. 1967. Some Observations on the Utilization of Sewage for Fish Culture in Oxidation Ponds. Environ. Health 9:156-161.

136. Chen, K. Y., C. S. Young, T. K. Jan, and N. Rohatgi. 1974. Trace Metals in Wastewater Effluents. J. Water Pollut. Control Fed. 46:2663-2675.

Because of the nature of its primary and secondary treatments and the discharge of wastewater and sludge effluents, the Hyperion Treatment Plant, Los Angeles, CA, was selected for an intensive study to characterize trace metals in the effluents of different treatment processes. The chief concern of the study was the partition of trace metals into the dissolved and particulate phases and the size distribution of the particulate borne fractions in wastewater effluents and digested sludge. With the exception of Ni, Mn, and Pb, secondary treatment was found to be moderately effective in removing trace metals in the particulate fraction. On a dry weight basis, trace metals in the particulate fractions of wastewater effluents and digested sludge were found to be within a narrow range. (AA)

137. Cheng, P. H. 1975. A Study on the Application of Biogrowth Sheets to Improve Lagoon Effluent Quality. Univ. of Missouri, Rolla. Dept. of Civil Engineering. Office of Water Research and Technology, Washington, DC.

Wastewater stabilization lagoons have been employed in small communities where available land and favorable climatic conditions allow for utilization as an economical secondary treatment process. Because of problems associated with the discharge of algae in the effluent, the traditional lagoon may require either some process modifications or additional effluent polishing processes in order to meet local water quality standards. The purpose of this study was to investigate the possibility of increasing attached algal growths on the surfaces of experimental biogrowth sheets to decrease algal discharges and improve the removal efficiency of organic materials as measured by Chemical Oxygen Demand. (NT)

138. Chesapeake Research Consortium Inc., Baltimore, MD. 1976. Five Year Program Assessment, 1970-1975. National Science Foundation, Washington, DC. 50 pp.

In 1970, the Office of Interdisciplinary Research Relevant to Problems of Our Society (IRRPOS) of the National Science Foundation made grants to the Johns Hopkins University, the University of Maryland, and the Virginia Institute of Marine Science for a research planning study of the Chesapeake Bay. The report's principal recommendation was the establishment of the Chesapeake Research Consortium (CRC) consisting initially of the three above-named institutions. Early in 1972, these institutions were formally joined by the Smithsonian Institution, which up to that time had been participating in the discussions on an observational basis. The CRC's research programs in the areas of wetlands, water quality, and wastewater are reviewed in this publication. The educational role of the CRC is discussed. (NT)

139. Chestnut, A. F. 1971. Structure and Functioning of Estuarine Ecosystems Exposed to Treated Sewage Wastes. Univ. of North Carolina, Inst. of Marine Sciences, Chapel Hill. 345 pp.

140. Chitty, N., and C. W. Davis (eds.). 1972. The Effects of the Discharge of Secondarily Treated Sewage Effluent into the Everglades Ecosystem. Sea Grant Spec. Bull. 6. Univ. of Miami, Miami, FL.

141. Cody, T. E., V. J. Elia, C. S. Clark, and R. T. Christian. 1979. Integrated Use of Bioassays and Chemical Analyses to Evaluate the Quality of Reuse Water, pp. 2230-2238. In American Water Works Association Research Foundation, Proceedings of the Water Reuse Symposium. Held 25-30 March at Washington, DC. Denver, CO.

142. Coldrick, J. 1975. Sewage as a resource. New Scientist 68:276.

Technical Feature: Physicists at the Wessex Authority are working on ways to minimize the economic reclamation of useful products from sewage. They have been successful in recovering industrial water, sludge gas, and soil conditioners. In the future they want to develop processes for recovering proteins, fine chemicals, and animal feed supplements. A process for using sludge gas for vehicle propulsion is described. In the Middle East and Far East, domestic waste and sewage are used to increase rural fish production. The nutrients in such wastes increase the productivity of fish ponds. The few attempts to use this technique in Europe have succeeded in raising annual fish production rates. This shows how a new cycle can be developed: the conversion of wastes into palatable protein via fish rearing. (2 photos). (EL)

143. Cole, D. P. (ed.). 1979. Proceedings of the Sixth Annual Conference on Wetlands Restoration and Creation. Hillsborough Community College, Tampa, Florida. Sponsored by the Tampa Port Authority and the Environmental Studies Center at Cockroach Bay, FL. 357 pp.

144. Cole, H., W. Merrill, F.L. Lukezic, and J.R. Bloom. 1969. Effects on Vegetation of Irrigation with Waste Treatment Effluents and Possible Plant Pathogen-irrigation Interactions. Phytopathology 59:1181-1191.

145. Cooke, W.B. 1956. Potential Plant Pathogenic Fungi in Sewage and Polluted Water. Plant Dis. Rep. 40:681-687.

146. Cooke, W.B. 1976. Fungi in Sewage. p. 389-434. In: E.B.G. Jones (ed.) Recent Advances in Aquatic Mycology. John Wiley & Sons, New York.

147. Coleman, M. S., J. P. Henderson, H. G. Chichester, and R. L. Carpenter. 1974. Aquaculture as a Means to Achieve Effluent Standards, pp. 199-215. In Wastewater Use in the Production of Food and Fiber Proc. EPA 660/2-74-041.

This paper presents an advanced biological system based on herbivorus or filter-feeding fish for the removal of algae. This system produces a useful product in the form of fish which may be used as bait, restocking, or forage. The Quail Creek Sewage Lagoons in Oklahoma City, OK, were used as a large scale test to fish viability.

148. Coler, R. A., and J. Pardo. 1977. A Test of the Effects of Domestic Sewage on the Growth of the Common Blue Mussel, Mytilus edulis, in an Aquaculture System. University of Massachusetts, Water Resources Center Publication No. 87, 44 pp. (AL)

The effects of domestic sewage on the growth rate of the marine bivalve mollusk, Mytilus edulis was investigated by introducing controlled amounts of sewage into a raceway system and comparing the response with that of organisms in a similar system fed with uncontaminated estuarine water. The results showed that the admixture of domestic sewage with sea water retarded the growth of this organism, and indicated that it would not be feasible to use populations of Mytilus to reduce the BOD due to sewage sludge in receiving waters. (AL)

149. Collins, E. R., Jr., E. T. Kornegay, and D. C. Martens. 1978. Swine Lagoon Effluent on a Soil-Plant Environment: An Impact Assessment. Virginia Water Resources Research Center Bulletin 110. Virginia Polytechnic Inst. and State Univ., Blacksburg, VA. 44 pp.

Two biological treatment units for a swine production unit were evaluated. One unit was maintained as an anaerobic system, the other as a mixed aerated unit by recirculation of effluent. Analysis of the supernatant of both systems showed that, with time, accumulation of heavy metals and other elements increased. Effluent from both treatment systems was irrigated on fescue plots, and effects on soil, soil water, and plant tissue were determined. While no visible deleterious effects were noted over a period of one and one half years, accumulation or high uptake of Na, Cu, and Zn was recorded in both plant tissue and soils. Nitrate leaching from plots was minimal. Other waste constituents measured did not appear to be limiting factors in land disposal of swine lagoon effluent. (NT)

150. Colt, J., S. Mitchell, G. Tchobanoglous, and A. Knight. 1979. The Use and Potential of Aquatic Species for Wastewater Treatment. Appendix B: The Environmental Requirements of Fish. California State Water Resources Control Board, Publication No. 65, Sacramento, CA, 240 pp.

151. Colt, J. et al. 1980a. The Use and Potential of Aquatic Species for Wastewater Treatment. Appendix C: The Environmental Requirements of Freshwater Crustaceans. California State Water Resources Control Board, Publication No. 65, Sacramento, CA.

152. Colt, J. et al. 1980b. The Use and Potential of Aquatic Species for Wastewater Treatment. Appendix D: The Environmental Requirements of Freshwater Bivalves. California State Water Resources Control Board, Publication No. 65, Sacramento, CA.

153. Copeland, B. J., and H. L. Davis. 1972. Estuarine Ecosystems and High Temperatures. North Carolina Water Resources Research Inst. Rept. No. 72-68. Raleigh, NC. 103 pp.

154. Copeland, B.J., H.T. Odum, and D.C. Cooper. 1972. Water Quality for Preservation of Estuarine Ecology, pp. 107-126. In: Conflicts in Water Resources Planning. Water Resource Symp. No. 5. Univ. of Texas, Austin.

Responses of estuarine community structure, respiration and production to added heat, sewage and their combination were investigated. Plastic pools containing transplanted ecosystems from South Creek Estuary, NC, were used. Temperature replication was achieved. Thermal treatment increased nutrient regeneration rates, yielding slightly higher algal biomass; although, seasonal differences were more significant. Sewage addition substantially increased ammonia levels, particularly during the winter. Community metabolism responded positively to thermal treatment, but not to sewage treatment. Temperature had very little effect on phytoplankton composition during the spring. A flow-through experiment was conducted to test more realistic estuarine conditions. Results were substantially the same as obtained under quiescent conditions. (NT)

155. Cornwell, D.A., J. Zoltek, Jr., C.D. Patrinely, T. deS. Furman, and J. I. Kim. 1977. Nutrient Removal by Water Hyacinths. J. Water Pollut. Control Fed. 49:57-65.

Water hyacinths (Eichhornia crassipes) were grown in polishing ponds containing secondary effluent from the University of Florida Campus Wastewater Treatment Plant. It was found that water hyacinths had an aera-doubling time of about 6 days when growing in secondary effluent compared to a 12 day area-doubling time under natural conditions. Nutrient removal was found to be less than 20 percent when the pond depth was 1.4m (4.5 ft) and the detention time was 15 h. Ponds with 0.34 m (1.1 ft) depth and 48 h detention time had 80 percent total nitrogen removal and 47 percent total phosphorus removal. A direct correlation was found to exist between the percent nutrient removal and a loading parameter defined as surface area per unit flow. (AA)

156. Costas, P. 1978. Potomac Estuary Tapped for Pilot Study. Water and Sewage Works 125(11):64.

Technical Feature: An experimental water treatment plant is being constructed to study the feasibility of using the Potomac Estuary as a water supply source. A water quality analysis program will assay raw, in process, and finished waters to evaluate the operating efficiency of various treatment processes and to determine the potability of the product water. The site for the plant was selected for its proximity to poor quality estuary water and wastewater treatment plant effluent. The estuary receives effluents from several water pollution control plants. During severe drought conditions, the percentage of treated wastewater in the estuary can be very high. Consequently, use of the estuary as a supplemental water supply source is still only a possibility. (EL)

157. Coupal, B., and J. Lalancette. 1976. The Treatment of Wastewaters with Peat Moss. Water Research 10:1071-1076.

158. Crisp, D. T. 1966. Input and Output of Minerals for an Area of Pennine Moorland: the Importance of Precipitation, Drainage, Peat erosion, and animals. J. Appl. Ecol. 3:327-348.

159. Culley, D. D., Jr., and E. A. Epps. 1973. Use of Duckweed for Waste Treatment and Animal Feed. J. Water Pollut. Control Fed. 45:337-347.

160. Czerwenka, W., and K. Seidel. 1976. The Combination of Biological and Chemical Treatment at the Krefield Water Treatment Works, pp. 287-293. In: J. Tourbier and R.W. Pierson, Jr. (eds.) Biological Control of Water Pollution. University of Pennsylvania Press, Philadelphia.

161. Damman, A.W.H. 1978. Distribution and Movement of Elements in Ombrotrophic Peat Bogs. Oikos 30:480-495.

162. Dane, C.W. 1959. Succession of Aquatic Plants in Small Artificial Marshes in New York State. New York Fish and Game Journal 6(10):57-76.

This report compares studies conducted in 1952, 1953, and 1956 in which successional changes in vegetation were measured and evaluated on 22 small marshes in the Southern Tier and Genesee-Niagara regions of New York. The latter region was found to be more favorable for abundance of emergent cover, abundance of subergent food, retainment of residual woody cover, slope of the marsh basin, and marsh-basin depths than the former region. Shallower flooding and a greater natural drawdown during the summer months permitted the woody cover to remain alive in the marshes of the Genessee-Niagara region, but the woody vegetation was largely flooded out in the Southern Tier.

The water level during the growing season was found to be the single most important factor in aquatic plant succession in marshes. Many of the marshes in the Southern Tier had slopes that dropped off sharply to 24 inches below the normal water level (the limit of regional emergents). Overcrowding of emergents occurred frequently in the shallower marshes of the Genessee-Niagara region during years with low water level. (EPA)

163. Darnell, R., W. E. Pequegrat, B. M. James, F. J. Benson, and R. A. Defenbaugh. 1976. Impacts of Construction Activities in Wetlands of the United States. EPA-600/3-76-045. U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR, 393 pp.

The primary types of construction activity which severely impact wetland environments of the United States include: floodplain surfacing and drainage, mining, impoundment, canalization, dredging and channelization, and bank and shoreline construction. Each type of construction activity is attended by an identification suite of physical and chemical alterations of the wetland environment which may extend for many miles from the site of construction and may persist for many years. In turn, each type of physical and chemical modification has been shown to induce a derived set of biological effects, many of which are predictable, in general, if not in specific detail. The most environmentally damaging effects of construction activities in wetland areas, in order of importance, are: direct habitat loss, addition of suspended solids, and modification of water levels and flow regimen. Major construction-related impacts also derive from altered water temperature, pH, nutrient levels, oxygen, carbon dioxide, hydrogen sulfide, and certain pollutants such as heavy metals, radioactive isotopes, and pesticides. Over one third of the nation's wetlands have been lost through various forms of direct habitat destruction, and well over half of the remainder have been severely modified. Many aquatic species are known to have been lost or severely restricted, and a number of species and habitats are currently in jeopardy, at least in part as a result of construction activities. Deliberate and drastic action is required to reverse the present trends, and recommendations are given for specific steps which must be taken to insure the survival of the wetland ecosystems of the nation. (AA)

164. Davis, A. C. 1980. Is This the Decade for Aquaculture? II. Compost Science/Land Utilization 81(2):37-39.

Some papers presented at a seminar on aquatic systems for purifying waste waters held at the University of California, Davis, are summarized. The Arkansas Game and Fish Commission are using silver and bighead carp for water quality improvement. These fin fish have especially adapted gill rakers efficient at filtering particles down to microns. Benton Wastewater Treatment Facility has a system of 6 sewage lagoons in series, the last 4 containing fish; BOD and suspended solids have been lowered by 96 and 86 per cent, respectively, with fish production of 5000 lb per acre year. Work at Michigan State University on ecological limits to the use of alternative systems of wastewater management is noted, as is a study of energy from wastewater aquaculture systems. The Denver Research

Institute is examining the legal, political, and social implications of wastewater treatment through aquaculture. (AL)

165. Davis, C.B, J.L Baker, A.G. Van der Valk, and C.E. Beer. 1981. Prairie Pothole Marshes as Traps for Nitrogen and Phosphorus in Agricultural Runoff, pp. 153-164. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

Water quality of drainage influents and the lone effluent at Eagle Lake marsh, Iowa, was studied for 4 years (1976-1979). Because of drought conditions, there was no effluent from the marsh in 1976, 1977, or 1978. In 1979, the marsh was effective at removing inorganic N, especially NO_3-N, from runoff water passing through. It has little impact on levels of inorganic-P, total-P, and Kjeldahl-N; it was a net exporter of soluble organic carbon. (AA)

166. Davis, G. J., and M. M. Brinson. 1980. Responses of Submersed Vascular Plant Communities to Environmental Change. U.S. Fish and Wildlife Service, FWS/OBS-79/33. 70 pp.

167. Davis, H. 1978a. Effects of the Treated Effluent on Mosquito Populations and Arbovirus Activity, pp. 361-428. In H.T. Odum and K. C. Ewel (eds.). Cypress Wetlands for Water Management, Recycling and Conservation, Fourth Annual Report. University of Florida, Gainesville.

168. Davis, H. G. 1978b. Recycling Treated Sewage through Florida Cypress Swamps: Its Effect on Mosquito Population and Arbo-virus Implications. Ph.D. Diss., Department of Entomology, University of Florida, Gainesville. 163 pp.

169. Davis, S.M., and L.A. Harris, 1978. Marsh Plant Production and Phosphorus Flux in Everglades Conservation Area 2. pp. 105-131, In: Drew, M.A. (Editor), Environmental Quality Through Wetlands Utilization. A Symposium on Freshwater Wetlands, 28 February-2 March 1978. The Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin, Tallahassee, FL.

170. Day, J.W., Jr., and G. Paul Kemp. 1983. Long-term Impacts of Agricultural Runoff in a Louisiana Swamp Forest (draft manuscript). In: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop, 23-25 June 1982, University of Massachusetts, Amherst, MA. US Fish and Wildlife Service and US Environmental Protection Agency.

171. Deghi, G.A., 1977. Effect of Sewage Effluent Application on Phosphorus Cycling in Cypress Domes. Master's Thesis University of Florida, Gainesville. 143 pp.

172. Deghi, G. S., K. C. Ewel, and W. Mitsch. 1980. Effects of Sewage Effluent Application on Litter Fall and Litter Composition in Cypress Swamps. J. of Applied Ecol. 17:397-408.

No increase in litter fall was observed after two years of addition of sewage to a cypress dome in northern Florida. The rate of decay of cypress needles in litter bags also was not observed to change in the presence of the effluent. The authors concluded that even if litter fall were to increase, litter accumulation probably would not increase. (EPA)

173. DeJong, J. 1976. The Purification of Wastewater with the Aid of Rush or Reed Ponds, pp. 161-172. *In* J. Tourbier and R. W. Pierson, Jr. (eds.). Biological Control of Water Pollution. University of Pennsylvania Press, Philadelphia, PA.

This research was performed in the Netherlands on artificial marshes constructed for the treatment of primary sewage effluent. Experimental treatment of the sewage of a camping site with a rush (*Scirpus lacustris*) pond, one hectare (2.5 acres) in size, began in 1967. In 1969, a number of experimental ditches for sewage treatment were dug that enabled a comparison of rushes, reeds (*Phragmites australis*), and polypropene fibers in purifying sewage. The aquatic plants functioned mainly by providing attachment sites for micro-organisms purifying the sewage and also consumed part of the nitrogen and phosphorus supplied to the pond. Research has been conducted at this site since 1967, and additional studies have been performed at a larger scale facility (a treatment plant of 40,000 population equivalents). (EPA)

174. DeJong, J. 1975. Bulrushes and Reed Ponds. Rijksdienst Voor de Ijsselmeer-polders. Flevobricht. N.R. 104.

175. Demgen, F. C. 1979. Water Used One More Time: Treated Wastewater for Wildlife. Outdoor California, pp. 28-29.

176. Demgen, F. C. 1979. Wetlands Creation for Habitat and Treatment - at Mt. View Sanitary District, California, pp. 61-73. *In* R. K. Bastian and S. K. Reed (eds.). Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division.

177. Demgen, F. C., and B. J. Blubough. 1977. Mt. View Sanitary District Marsh Enhancement Pilot Program. Progress report No. 3, Contra Costa County, CA, 50 pp.

178. Demgen, F. C., and J. W. Nute. 1977. Marsh Enhancement Program: Conceptual Plan for Mt. View Sanitary District, Contra Costa County, CA, 143 pp.

179. Demgen, F. C., and J. W. Nute. Wetlands Enhancement Using Secondary Effluent. Presented at the National Conference on Environmental Engineering, Research Development and Design. Kansas City, MO. 10-12 July 1978.

180. Demgen, F. C., and J. W. Nute. Wetlands Creation Using Secondary Treated Wastewater. Presented at the AWWA Research Foundation Water Reuse Symposium. Washington, DC. March 25-30, 1979.

Technical Feature: The concept of using treated sewage effluent as a freshwater source for the creation and restoration of wetland ecosystems of San Francisco Bay is investigated. The wetlands habitats, including vegetation and wildlife, and wetlands restoration facilities are described. Water quality characteristics of the effluent, such as DO, BOD, suspended solids, and nutrients, are surveyed. The benefits of this wetlands system include improved water quality, habitat creation or enhancement, and recreational and educational opportunties. (EL)

181. deMichel, E., and R. M. Trip. 1975. Estimate of Treatment Plant Effluent Impact on Chloride Concentrations and Oyster Environment within the Murderkill Estuary. Water Research 9(12):1107.

Technical Report: The effect of treatment plant effluent on chloride concentrations and oyster environment within the Murderkill River Estuary, DE, is investigated. Use of a one-dimensional steady state model for a conservative substance shows that chloride values would be reduced by up to 20% at low water slack periods for wastewater flows of 10 MGD-1. Chloride additions in the treatment plant effluent should be implemented to maintain minimum summertime low water slack levels of 5.6 PPT, consistent with a proper environment for oyster development. (EL)

182. DePauw, N. et al. 1976. Research on the Tertiary Treatment of Swine Waste by Mass Culturing of Algae. International Symposium on "Experimental Use of Algal Cultures in Limnology", Sandefjord, Norway, Oct. 26-28, 1976.

183. DePauw, N. and L. Deleenheer. 1977. Mass Culturing of Marine and Freshwater Algae on Aerated Swine Manure. Presented at the Conference: "Cultivation of Fish Fry and its Live Food", Szymbark, Poland, Sept., 23-28, 1977.

184. Dewitt, C.B. and E. Soloway (eds.), 1978. Wetlands: Ecology, Values, and Impacts. Proceedings of the Waubesa Conference on Wetlands, June 2-5, 1977. Madison, WI. 388 pp.

The 27 papers presented in the proceedings of the Waubesa Conference on Wetlands are grouped into eight categories: wetland soils, nutrition, and productivity, environmental impacts, wetland protection and restoration, wetlands for wastewater treatment, wetland system studies, wetland animals, wetland mapping, and patterns and dynamics of wetland communities. The abstracts of seven papers not presented in this volume are presented in Appendix 1. A majority of the papers deal with the wetlands of Wisconsin. A list of films on wetlands and related topics, excerpts from the conference program and an index are provided.

185. Dickson, K. L., J. Cairns, Jr., J. R. Clark, and J. H. Rodgers. 1978. Evaluating Pollution Stress on Ecosystems, pp. 80-83. In K. C. Flynn, and W. T. Mason (eds.). The Freshwater Potomac - Aquatic Communities and Environmental Stresses. Proceedings of a symposium held in January 1977 at College Park, MD. Interstate Commission on the Potomac River Basin, Rockville, MD.

186. Dierberg, F. E., and P. L. Brezonik. 1976. Denitrification and Surface Runoff in the Experimental Domes, pp. 353-374. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

187. Dierberg, F.E., and P.L. Brezonik. 1978. The Effects of Secondary Sewage Effluent on the Surface Water and Groundwater Quality of Cypress Domes, pp. 178-270. In: H.T. Odum and K.C. Ewel (eds.). Cypress Wetlands for Water Management, Recycling, and Conservation. Fourth Annual Report to the National Science Foundation and the Rockefeller Foundation. Center for Wetlands, University of Florida, Gainesville.

188. Dierberg, F.E., 1980. The Effects of Secondary Sewage Effluent on the Water Quality, Nutrient Cycles and Mass Balances, and Accumulation of Soil Organic Matter in Cypress Domes. Ph.D. Dissertation. University of Florida, Gainesville. 324 pp.

The capability of cypress domes to act as efficient nutrient traps has been demonstrated for a natural and sewage-enriched cypress dome. Mass balance models indicated that 87% of the nitrogen and 92% of the phosphorus loadings were retained within a cypress dome receiving secondary sewage effluent, removal efficiencies that are among the highest reported for any wetland ecosystem receiving treated sewage. Thus, cypress domes seem to be effective natural tertiary treatment systems. Field data and laboratory investigations demonstrated that denitrification was a major nitrogen sink in both natural and sewage-enriched domes. Bulk precipitation was the most important factor in supplying new minerals and nutrients (except nitrogen) to the natural cypress dome. Analyses of standing waters of natural and sewage-enriched cypress domes near Gainesville, Florida, over a 4.5 year period showed that discharge of secondary sewage effluent altered the soft, acid water found in natural domes to a neutral, moderately hard condition. Furthermore, the absence of dissolved oxygen, high levels of phosphorus, nitrogen, biochemical oxygen demand, and the presence of hydrogen sulfide mean that treated sewage effluent has a substantial impact on water quality. Water samples from shallow wells, ceramic soil moisture tubes, and laboratory percolation columns indicated that the underlying organic matter and sands were serving as an effective barrier to the transport of sewage pollutants to the shallow aquifer immediately below.

189. Dinges, R. 1973. Ecology of Daphnia in Stabilization Ponds. Texas State Department of Health Resources, Austin, TX., pp. 133-136.

The objectives of this report were: to locate Texas wastewater stabilization ponds supporting Daphnia populations and identify those environmental factors which are favorable, or inimical to Daphnia, and to use information acquired in field studies of "Daphnia Ponds" to establish a pilot pond for maintenance of a mass Daphnia culture to use in clarification of stabilization pond effluent. (NT)

190. Dinges, R. 1974. The Availability of Daphnia for Water Quality Improvement and as Animal Food Source, pp. 142-161. In Wastewater Use in the Production of Food and Fiber-Proc. U. S. Environmental Protection Agency. Ada, OK.

191. Dinges, R. 1976a. A Proposed Integrated Biological Wastewater Treatment System, pp. 225-230. In J. Tourbier and R. W. Pierson, Jr. (ed.). Biological Control of Water Pollution. University of Pennsylvania Press, Philadelphia, PA.

Construction of an experimental facility at an area wastewater treatment plant is underway to evaluate potential employment of various animals and plants in an integrated, sequenced system for improvement of water quality. The wastewater treatment plant consists of an aeration basin, clarifier, and three stabilization ponds operated in series. Input to the experimental unit will be a portion of the effluent from the terminal stabilization pond.

Stabilization pond effluent in which original organic material has been reduced by bacterial action and converted into algae cells would be of high quality except for algae present and high bacteria and nutrient levels. The study scheduled to commence in the near future will incorporate information gained from past studies and include several new concepts. It is intended to correct the deficiency of stabilization pond effluent quality.

192. Dinges, R. 1976b. Water Hyacinth Culture for Wastewater Treatment. Texas Department of Health, Division of Wastewater Technology and Surveillance, Austin, TX. 143 pp.

193. Dinges, R. 1976c. Who Says Sewage Plants have to be Ugly? Water and Wastes Engineering 13(4):20-23.

194. Dinges. R. 1978. Upgrading Stabilization Pond Effluent by Water Hyacinth Culture. J. Water Pollut. Control Fed. 50(5):833-845.

Water hyacinths (Eichhornia crassipes) were grown in a series of four earthen basins provided with stabilization pond effluent to determine the effect of their cultilvation on water quality. System effluent contained less than 10 mg/l of suspended solids of 5-day biochemical oxygen demand. Significant reductions in fecal bacteria and nitrogen were recorded. Most of the improvement in quality obtained may be attributed to the unique habitat afforded by a dense stand of hyacinths. Mineral nutrients and heavy metals were accumulated by the plants during active growth. Basic culture basin design considerations and the potential applications of hyacinth treatment are discussed. (AA)

195. Dinges, R. 1979. Development of Hyacinth Wastewater Treatment Systems in Texas, pp. 193-226. In R. K. Bastian and S. C. Reed (eds.). Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. U.S. Environmental Protection Agency. Office of Water Program Operations, Municipal Construction Division. EPA 430/9-80-006.

There is sufficient information available for designing hyacinth treatment facilities to be employed in warm climates. The optimal design of culture basins is necessary to minimize areal requirements and greenhouse costs in temperate climates. Hydraulic loading is the most critical consideration in culture basin design. The primary pollutant removal mechanism of hyacinth treatment is the reduction of suspended particulate content. The harvesting of hyacinths disrupts treatment. Provision of multiple culture basins to allow alternate operation is desirable. Each culture basin should be drained and the accumulated sludge and plant debris removed on an annual basis. Hyacinth culture may be employed as a complete treatment process. Nitrogen management is a key factor in utilizing hyacinths for wastewater treatment, or for biomass production. Stabilization ponds can be designed for effective nitrogen reduction. Hyacinth culture will remove most remaining nitrogen in pond effluent, especially that which is in the organic form. Stabilization ponds followed by hyacinth culture constitutes a highly effective wastewater treatment system. A hyacinth treatment system is capable of producing effluent having a mean content of <10mg/l BOD_5 and TSS. (AA)

196. D'Itri, F.M. (ed.). 1977. Wastewater Renovation and Reuse. Marcel Dekker, Inc., New York.

197. D'Itri, F.M. (ed.). 1981. Vegetation Management for Land Treatment of Municipal Wastewater. Great Lakes National Program Office U.S. Environmental Protection Agency. Chicago, IL. 163 pp.

A conference/workshop was held at Michigan State University on February 23-25, 1981, to review, discuss, and recommend vegetation management strategies and cultivars which can be used most effectively in slow rate and overland flow municipal land treatment systems in the north central region of the United States. Eleven research papers were presented on various aspects of vegetation selection and management such as (a) irrigation system design, (b) wastewater crop management, (c) vegetation selection and management for overland flow systems, (d) tree and old field responses to wastewater irrigation, and (e) plant diseases associated with municipal wastewater irrigation. The participants and audience for the conference consisted of scientists, wastewater treatment plant operators, and state and local governmental officials.

The workshop phase was limited to the speakers and Environmental Protection Agency representatives. They evaluated more fully the information presented during the conference to summarize the current state of the art and identify future research needs.

198. Dixon, K. R., and J. A. Kadlec. 1975. A Model for Predicting the Effects of Sewage Effluent on Wetland Ecosystems. Wetlands Ecosystem Research Group. Univ. of Michigan, Ann Arbor.

This report examines a mathematical model of the organic matter components of a wetland ecosystem--its objective, its development, and its analysis. The objective of the model is to be able to forecast the effects of sewage wastewater disposal on the ecosystem; this requires that the variables of water and nutrients be included in the models of the several processes which may be affected by the wastewater disposal. The model consists of a set of ordinary first-order, nonlinear differential equations representing the mass balance of the biomass components of the system. Its analysis indicates the model's credibility as a first-time model that can be used as an aid in making decisions about the feasibility of using a wetland ecosystem for wastewater disposal. (NT)

199. Dodge, D. E. 1972. Avian Botulism: Factors Affecting its Occurrence on Domestic Sewage Lagoons. Master's Thesis, Utah State University, Logan. 101 pp.

The sewage lagoons for the city of Logan, Utah, were investigated for factors which are conducive to the death of ducks and other water birds by botulism. Observations on waterfowl populations in relation to botulism were conducted during the summer and fall of 1970 and 1971. Ecological features of the lagoons were also studied to determine if outbreaks were related to ecological phenomena.

During 1970 approximately 140 birds died from botulism between August 14 and September 30. In 1971 35 birds died between August 11 and September 15. Data for 1969 showed that approximately 2000 birds died between July and September of that year. Botulism losses all 3 years correlatd with peaks in the invertebrate populations, especially chironomid larvae, in some of the ponds and with large blooms of the blue-green algal *Microcystis aeruginosa*. The decreasing severity of the botulism outbreaks from 1969 to 1971 was probably the result of several factors. The abundance of chironomids in the sediment of lagoons appeared to decline from 1969 to 1971, the toxigenicity of the botulinum bacteria in the lagoons may have been reduced from 1969 to 1971, and the number of decaying bird carcasses left on the lagoon ponds was less in 1970 and 1971 than in 1969. (AA)

200. Dolan, T. 1978. Effect of Sewage Effluent on the Phosphorus Budget of a Marsh. Master's Thesis. Department of Environmental Engineering Sciences. University of Florida, Gainesville. 77 pp.

201. Dolan, T.J., S.E. Bayley, J. Zoltek, Jr., and A. Hermann. 1978. The Clermont Project: Renovation of Treated Effluent by a Freshwater Marsh, pp. 132-152. *In* M. A. Drew (ed.), Environmental Quality through Wetlands Utilization. Proceedings of a symposium held 28 February-2 March 1978, at Tallahassee, FL. sponsored by the Coordinating Council on the Restoraton of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin. Tallahassee, FL.

202. Dolan, T.J., S.E. Bayley, J. Zoltek, Jr., and A.J. Hermann. 1981. Phosphorus Dynamics of a Florida Freshwater Marsh Receiving Treated Wastewater. Journal of App. Ecol. 18(1):205-219.

Phosphorus in secondary effluent, applied weekly for a year to a test plot, was over 97% assimilated. Soil (peat, clay, and sand) was the major sink, with secondary sinks in the below-ground biomass and litter. Three 2000 sq. meter plots received effluent at the rates of 1.3, 3.8, and 10.2 cm per week, with a control plot receiving 3.8 cm per week of freshwater. Vegetation present included *Sagittaria lancifolia*, *Pontederia cordata*, *Panicum spp*. and *Hibiscus sp*. The plot with the highest rate of effluent loading showed increases in net production of plant shoots, litter, root and rhizomes, and in P concentration in living and dead plant tissue, compared with the control plot. There was 38.03 g P per sq meter applied to the high effluent plot during the course of the study; 26.31, 8.81, and 1.97 g P per sq meter were stored in soil, roots and rhizomes, and litter, respectively. Outflow from the plot was 0.94 g P per sq meter. The freshwater control plot received a total of 0.38 g P per sq meter, stored 0.21 g P per sq meter in the litter, and lost 0.17 g P per sq meter in the outflow. There was no evidence of a spring flush of P from any plot.

203. Dollar, S. J. 1979. Ecological Response to Relaxation of Sewage Stress Off Sand Island, Oahu, HI. Rept. No. 124. Univ. of Hawaii, Oahu.

204. Donaszy, E. 1974. Principles of Sewage Treatment through Utilization in Fish Ponds, pp. 546-547. *In* Wastewater Use in the Production of Food and Fiber-Proc. U. S. Environmental Protection Agency. Ada, OK.

205. Dovovan, J.F. and J.E. Bates, 1980. Guidelines for Water Reuse. EPA Report No. EPA-600/8-80-036. August. 115 p.

In order to increase interest in and assist implementation of wastewater reuse for nonpotable purposes, guidelines have been developed to make water managers and resource planners aware of proven reuse possibilities. Perceived benefits in water reuse include: conservation of water; recycling of nutrients; practical cost and energy savings; reduction in the discharge of pollutants; realization of other public priorities such as preservation of open space for aesthetic and recreation value; and encouragement of industrial recycling. Following a step-by-step approach provided in the guidelines, the water manager and resource planner can address the principle areas of concern in water reuse programs, including technology, economics, legal issues, institutional arrangements, markets, and public information. Case histories provide insight into actual reuse experience. Potential markets for reclaimed water include: groundwater recharge; recreation; environmental enhancement.

206. Dorris, T. C., S. L. Burks, and G. R. Waller. 1974. Effects of Residual Toxins in Oil Refinery Effluents on Aquatic Organisms. Technical Completion Report, Oklahoma Water Resources Research Inst., Stillwater, OK. 81 pp.

Laboratory evaluations of partial evaporation of oil refinery wastewaters were performed to determine removal of toxic substances by partial evaporation, suitability of discharge to a receiving stream of the bottom partially concentrated waters from an evaporator, and acceptability of overhead evaporator product water for reuse as boiler make-up or other uses. The wastewaters from biological treatment--lagoon and activated sludge units-and from primary treatment facilities--API separator and air flotation--were partially evaporated in rotating thin-film or columnar falling film evaporators. Conclusions were that partial evaporation of biological treated oil refinery wastewater, removes toxic substances from biologically treated oil refinery wastewaters, produces an overhead product water which has low inorganic salt concentration and should be reusable for boiler make-up or other uses where high-quality water is desirable, and produces a partially concentrated bottom product water generally less toxic. (NT)

207. Dressler, R. L., and G. W. Wood. 1976. Deer Habitat Response to Irrigation with Municipal Wastewater. J. Wildl. Manage. 40(4):639-644.

The influence of wastewater irrigation on the quantity and quality of forage production and white-tailed deer (Odocoileus virginianus) feeding response was studied in central Pennsylvania. Little difference was found in the amounts of available forage during the early spring months. During the growing season the production of palatable forage on the irrigated site was considerably less than on the non-irrigated site. Concentrations of crude protein, P, K, and Mg in forage generally were increased by irrigation as was present digestible dry matter. Observations of semi-free ranging lead deer did not indicate any deterrence from use of the site due to wastewater irrigation. (AA)

208. Drew, M. L. 1975. Decomposition of Cypress Dome Litterfall by Fungal Populations. Master's Thesis, Department of Environmental Engineering Sciences, Univ. of Florida, Gainesville. 75 pp.

209. Drew, J. A. (ed.). 1978. Environmental Quality through Wetland Utilization. Proceedings of a symposium held 8 February-2 March 1978, at Tallahassee, FL. Sponsored by the Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin. Tallahassee, FL. 743 pp.

210. Drifmeyer, J.E., and W. Odum. 1975. Lead, Zinc, and Manganese in Dredge-Spoil Pond Ecosystems in Virginia. Environ. Conserv. 2:1-7.

211. Duever, M.J., J.E. Carlson, L.A. Riopelle, and L.C. Duever. 1977. Ecosystem Analysis at Corkscrew Swamp. Pages 534-570. In: H.T. Odum and K.C. Ewel (eds.), Cypress Wetlands for Water Management, Recycling and Conservation. 4th Annual Report to the National Science Foundation and the Rockefeller Foundation, Center for Wetlands, University of Florida, Gainesville.

212. Duffer, W. R., and C. C. Harlin. 1979. Potential of Aquaculture for Reclamation of Municipal Wastewater, pp. 740-747. In AWWA Research Foundation, Proceedings of the Water Reuse Symposium, Vol. I.

Survey Report: Wastewater aquaculture is surveyed. Federal R & D programs concerning wastewater reuse in aquaculture facilities are summarized. Production aquaculture is differentiated from treatment process aquaculture. The latter emphasizes the culture of organisms for wastewater treatment and management, and the former emphasizes production. Research needs concern aquatic macrophytes, wetlands, food chain processes, economic evaluations, finfish, and invertebrates.

213. Duffer, W. R., and J. E. Moyer. 1978. Municipal Wastewater Aquaculture. EPA-600/2-78-110. U.S. Environmental Protection Agency, Wastewater Management Branch, Robert S. Kerr Environmental Research Laboratory, Ada, OK. 47 pp.

The developmental status of the aquacultural alternative for treatment and reuse of municipal wastewater was reviewed. Major emphasis was given to the reduction or fate of pollutants in such areas as organics, solids, nutrients, heavy metals, residual hydrocarbons, and potentially pathogenic organisms. Economic assessments of treatment and production rates for organisms were included for several types of aquacultural processes. wetlands, macrophytes, invertebrates, fish and integrated or food chain units. Based on the literature examined, the information available at this time is not adequate for the design of operational aquaculture systems to treat or utilize inputs of municipal wastewater. Sufficient exploratory studies have been conducted, however, to demonstrate a definite potential for development of wastewater aquaculture systems. Areas having high potential for further research and development were identified. This report covers recent research progress in municipal wastewater aquaculture as of June 1977. (AA)

214. Dunigan, E. P., R. A. Phelan, and Z. H. Shamsuddin. 1975. Use of Water Hyacinths to Remove Nitrogen and Phosphorus from Eutrophic Waters. Hyacinth Control J. 13:59-61.

215. Dunstan, W.M., and K.R. Tenore. 1972. Intensive Outdoor Culture of Marine Phytoplankton Enriched with Treated Sewage Effluent. Aquaculture 1: 181-192.

The authors describe studies on the development of a combined tertiary sewage treatment and aquaculture system in which the effluent from secondary sewage treatment is used as a growth medium for unicellular marine algae, and the algae, in turn, are used as food for bivalve molluscs. Under outdoor conditions, the sewage enrichment of sea water stimulated the growth of a variety of micro-algae which were usually dominant in the water before enrichment. Several sources and samples of sewage effluent were successfully used for enrichment. (AL)

216. Dunstan, W.M. and K.R. Tenore, 1974. Control of Species Composition in Enriched Mass Cultures of Natural Phytoplankton Populations. J. Appl. Ecol. 11(2):529-536.

The changes in species composition of intensively harvested outdoor cultures of enriched natural populations of micro-algae were studied using a variety of nutrient additions and dilution rates. The control of species in such semi-continuous outdoor cultures is not only important for aquaculture systems but is also helpful in identifying the effects of eutrophication on coastal phytoplankton populations. In a series of 3 experiments in which cells were counted and identified during the 6th-10th day of the daily 50% harvest, N, P and SI definitely favored the growth of diatoms. The addition of just N and P or N, P and trace metals stimulated a green microalgae population. Addition of treated sewage effluent resulted in a 70-80% diatom culture. In another series of experiments the rate of daily dilution was varied and in 2 experiments in June a clear control of species composition resulted. In 10% daily dilution green micro-algae dominated while at 75% dilution diatoms dominated particularly *Skeletonema costatum* (now *Stephanopyxis costata*). The results from experiments in July and August were not as definitive as those in June and the ubiquitous diatom *Cylindrotheca closterium* prevailed at all dilution rates.

217. Dunstan, W. M., and H. L. Windom. 1975. The Influence of Environmental Changes in Heavy Metal Concentrations of *Spartina alterniflora*, pp. 393-404. *In* L. E. Cronin (ed.), Estuarine Research, Vol. II, Geology and Engineering. Academic Press, NY.

218. Dworkin, J. M. 1978. Wastewater Management and Decision-Making: The Role of Community Acceptance in the Adoption of Land Treatment. Ph.D. Diss., Dept. of Geography, Clark University, Worchester, MA. 246 pp.

219. Dykyjova', D. and J. Kvet (ed.). Pond Littoral Ecosystems: Structure and Functioning. Springer-Verlag, New York. 1978.

The book is the result of the Czechoslovak IBP wetlands project which focused on intense quantitative ecological investigations of shallow littoral ecosystems of typical Central European fishponds. The book is divided into several sections: (i) General ecology and inventorization of biotic communities, (ii) Environmental factors in fish pond littoral, (iii) Primary production and production processes in littoral communities, (iv) Structure and functioning of algal communities in fish ponds, (v) Decomposition processes in the fish pond littoral, (vi) Structure and role of animal populations in fish pond littoral, (vii) Effect of fish pond management on the littoral communities, and (viii) Conservation of plant communities and waterfowl in wetlands of Czechoslovakia. The largest section was section 3 on primary production. Generally, the book is a compilation of data generated by the various studies with little transition from one section to another and, although one section will refer to another, the editors made very little effort to tie the material together. As stated by the editors "the volume does not present a final synthesis in the form of overall ecosystems budgets and models, but the editors have attempted to give as much as possible for condensed quantitative data as is needed for syntheses and ecosystem modeling." This book would probably be a good reference work for a library, but individual researchers should examine a copy before ordering one for their personal reference.

220. EBC Company. 1979. The Marsh-Forest System: A Pleasant and Positive Answer for Water Reclamation.

221. Ecology Consultants. 1977. Reclamation for Wildlife Habitat. In: Proceedings of the Reclamation Workshop, Ft. Colllins, CO.

222. Eckenfelder, W. W., and M. P. Wanielista. 1978. Advances in Water and Wastewater Treatment. Biological Nutrient Removal. Ann Arbor Science Publishers, Inc. Ann Arbor, MI. 286 pp.

The present status of biological nutrient removal systems is reviewed. Kinetics of relevant biochemical reactions and the design and operation of a number of different practical treatment systems and equipment are discussed. The roles of water hyacinths and of cypress swamps in decreasing or eliminating the nutrient load are considered. A separate chapter is devoted to the operation of biological fluidized beds for nitrogen control. (AL)

223. Edeline, F., and G. Lambert. 1974. A Simple Simulation Method for River Self-purification Studies. Water Res. 8(5):297-306.

224. Edds, G.T. and J.M. Davidson. 1981. Sewage Sludge Viral and Pathogenic Agents in Soil-Plant-Animal Systems. U.S. Environmental Protection Agency. Pub. No. EPA-600/51-81-026. Health Effects Research Lab. Cincinnati, OH.

In this study, a multi-disciplinary approach was used to determine the ultimate fate of various toxic elements or pathogens associated with Florida and Chicago municipal sludges when applied to soil-plant-water systems as an alternative method for the utilization of recycled digested municipal sludge. Determination was made of the physiologic, pathologic, growth, and reproductive responses of cattle, swine, and poultry that were fed sludges, grains or forages from soils pretreated with urban liquid digested sludges, as well as health effects in mice receiving liver or kidney tissues from steers and swine exposed to such feeds or contaminants.

There were minimal differences in growth performance or egg production in cattle, swine, or poultry fed forage or grain from soils pretreated with a variety of urban sewage sludges. Cattle and swine tissues, when fed to mice, resulted in alterations of the normal mineral balance as well as reproductive performance. Tissues from animals intended for human consumption exposed to sarcocyst contaminated sewage sludges may serve as health hazards for animals and humans.

Application of urban sludges at 19.8 ton/hectare produced equivalent plant growth stimulation for corn, barley, wheat, and sorghum as commercial fertilizers. Certain bacteria, commonly associated with sludges, disappear in a few days after soil or plant application. However, certain viruses and parasites were shown to persist. New and improved methods were developed to monitor persistence as well as assay for the presence of drugs or other hazardous materials.

225. Eisenberg, D. M., J. Benemann, and J. Weissman. Recent Advances in the Utilization of High Rate Photosynthetic Wastewater Treatment Systems: Potential for Reclamation of Municipal and Agricultural Tastewater. Presented at the Water Reuse Symposium II. Washington, DC. Aug. 23-29, 1981.

Wastewater stabilization ponds have long been recognized as a low-cost alternative for the treatment of many types of wastewater. The uncontrolled environment within ponds of conventional design, however, has often resulted in unreliable performance. This and the difficulty of removal of algal suspended solids from the pond effluents have caused engineers to no longer design this type of system, and many existing systems have been abandoned in favor of conventional wastewater treatment plants which are most costly and more energy intensive.

With the recent development, at the University of California Sanitary Engineering Research Laboratory, of the paddlewheel mixed high rate stabilization pond, an intermediate alternative has become available. These ponds provide a degree of control which cannot be achieved in conventional ponds with only a small increase in cost and energy consumption. They make use of intensive photosynthetic oxygenation and high algal productivity to produce high quality reclaimed water and algal-bacterial flocs which are of relatively large size and thus can be readily removed.

In this paper the principals of operation will be described as well as the details of contruction of the experimental ponds at University of California. Data on wastewater treatment and algal productivity will be presented from two years of continuous pond operation. The implications of this data will be discussed with emphasis on the effectiveness of treating water for reclamation purposes.

Two possible applications outside of the municipal wastewater treatment field will be discussed. These are the reclamation of agricultural drainage water from California's Imperial Valley and the on-site reclamation of wastewater generated in daily, poultry, and livestock operations. In addition to water reclamation both of these applications have enormous potential for generation of valuable by-products ranging from methane gas or electricity to expensive aquaculture products for human consumption. (AA)

226. Engler, R.M., D.A. Antie and W.H. Patrick, Jr. 1976. Effect of Dissolved Oxygen and Redox Potential and Nitrate Removal in Flooded Swamp and Marsh Soils. J. Environ. Qual. 5(3):230-235.

Flooded and marsh soils in the interior swamp and coastal areas of Louisiana have a high capacity for removing NO_3. Nitrate added either to the shallow floodwater or mixed in the soil rapidly disappeared under laboratory conditions. Nitrate loss does not take place in the floodwater, but is dependent on the NO_3 moving downward into the anaerobic soil layer. The NO_3 removal capacity is much greater than is required to handle any amount of No_3 -N that is likely to be present in these areas, either from oxidation or ammonium, that has been released from organic matter or from NO_3 derived from local runoff from adjacent agricultural areas. Nitrate loss does not appear to be inhibited by the presence of a small amount of molecular 0_2 in flooded soils.

227. Engler, R. M., and W. H. Patrick, Jr. 1974. Nitrate Removal from Floodwater Overlying Flooded Soils and Sediments. J. Environ. Qual. 34:409-415.

The floodwater nitrate removal rate of intermittently flooded fresh swamp soils and continuously flooded saline marine soils in southern Louisiana is quantitatively characterized. Of the two areas studied, the marsh area is the more effective sink for nitrate contaminated waters.

228. Enns, W. R. 1967. Insects Associated with Midwestern Oxidation Lagoons. Terminal Progress Report. Univ. of Missouri, Columbia. 21 pp.

The aim of this project was to study the entomological fauna of sewage lagoons. Fauna studied included insects, crustacea, mites, spiders, and sowbugs. Studies were conducted in different types of lagoons from the newest, rawest ones to old ones; these were both primary and secondary lagoons. Other areas of investigation included; predator prey species in the lagoons and determination of predators most effective in supressing midges and mosquitoes; presence of insect pathogens and whether they could be manipulated artificially; and the possibility of manipulating insect populations to maintain a balanced lagoon.

229. Epstein, L., K. Ditz, and G.R. Safir. 1982. Plant Disease in an Old Field Ecosystem Irrigated with Municipal Waste Water. J. of Environ. Qual. 11:65-68.

During 1978 and 1979, plant disease on foliage was assessed in an old field dominated by goldenrod (Solidago canadensis and S. graminifolia) and quackgrass (Agropyron repens) and irrigated with waste water. Plant pathogens abundant in waste-water-irrigated areas included, Coleosporium asterum, Erysiphe cichoracearum, Phyllachora graminis, and Helminthosporium sp.; such fungi reportedly alternate their life cycles or reproduce on economically important plant species. The increased foliar disease in the irrigated areas was probably due to increased moisture. Frequencies of plant pathogens in the waste water were apparently low since wounded seedlings of numerous crop varieties immersed in waste water remained healthy. *Alternaria alternata* and *Stemphylium sarcinaeforme* survived equally well after 24 days in filter-sterilized waste water or tapwater; however, *Erwinia herbicola* and *E. atroseptica* survived longer than 24 hours in buffered tapwater. (AA)

230. Epstein, L. and G.R. Safir. 1981. Plant Diseases Associated with Municipal Wastewater Irrigation. pp. 157-161. Paper presented at the Conference on Vegetation Management for Municipal Wastewater Land Application Systems: Great Lakes Region of the United States, held at Michigan State University, East Lansing, MI, 23-24 February 1981, preliminary draft of the proceedings. Kellogg Center for Continuing Education, Michigan State University, East Lansing, MI, 15 p.

Over a 24 day period, 0.1 ml aliquots of wastewater or tap water were plated onto potato dextrose agar in order to monitor populations. No differences in the survival of the spores in tap and wastewater were noted. It is believed plant parasites and saprophytes compete for nutrients in exudates found on plant surfaces. To examine this interaction, we monitored the short term survival of a phytopathogenic bacterium, *Erwinia herbicola*, in wastewater and tap water. A sterile dilute phosphate buffer was added to filter-sterilized wastewater or tap water with or without 0.1 percent yeast extract (to simulate plant exudate). After inoculation with a uniform bacterial suspension containing approximately 10^5 cells/ml, the flasks were shaken for 24 hr. Populations at 0 and 24 hr after inoculation were determined with a dilution series of the liquid on yeast extract agar. Both the pathogenic and the saprophytic *Erwinia* species survived better in the wastewater than in the tap water, but grew more rapidly in the simulated leaf exudate in tap water than in simulated leaf exudate in wastewater.

231. Erlich, S. 1966. Two Experiments in Biological Clarification of Stabilization Pond Effluents. Hydrobiologia 27:70-80.

232. Estrada, M., I. Valiela, and J. M. Teal. 1974. Concentration and Distribution of Chlorophyll in Fertilized Plots in a Massachusetts Salt Marsh. Sea Grant Rept. No. 74-03. Center for Wetland Resources, Louisiana State Univ., Baton Rouge. 30 pp.

233. Evans, D. W., and J. P. Giesy. 1978. Trace Metal Concentrations in a Stream-Swamp System Receiving Coal Ash Effluent, pp. 782-791. *In* Proceedings of the Intl. Congress for Energy and Ecosystem Ecol. and Coal Resource Devel. Conf. Vol. 2. Grand Forks.

Water, suspended solids, and emergent plants were analyzed for trace metal concentrations in a stream-swamp ecosystem receiving effluents from a coal ash disposal basin in South Carolina. Samples were analyzed for cadmium, cobalt, chromium, copper, iron, manganese, molybdenum, nickel, lead, and zinc. Results from the polluted stream are compared with those from a stream not receiving ash effluents. The effluent-receiving stream showed small elevations in metal levels in biotic and abiotic components compared with the control stream. (EL)

234. Everest, J.W. and D.E. Davis. 1979. Studies of Phosphorus Movement Using Salt Marsh Microecosystems. J. Environ. Qual. 8(4):465.

Microecosystems of a salt marsh community were designed, constructed, and used to follow phosphorus flux through the physical and biological components of that community. The biological components in these microecosystems were smooth cordgrass (Spartina alterniflora Loisel), diatoms, mud fiddler crabs (Uca pugnax Smith), periwinkle snails (Littorina irrorata Say), and ribbed mussels (Geukensia demissa Diliwyn; formerly Modiolus demissus Dillwyn). The physical components were the marsh soil and the seawater. Phosphorus (P) placed 17.5 cm below the soil surface was abundantly present in the smooth cordgrass leaves and on the soil surface 4 days later. No P was secreted by the leaves of smooth cordgrass during the experiment. The rapid transfer of phosphorus to the soil surface was found to be the result of the burrowing activity of the fiddler crab. (AA)

235. Ewel, K.C., 1976a. Changes in Understory Vegetation in Cypress Domes Brought About By Fire and Addition of Sewage. pp. 171-189. In: Third Annual Report on Cypress Wetlands, University of Florida, Center for Wetlands, Gainesville.

The effects of application of groundwater and sewage on ecological relationships in burned and unburned cypress domes was monitored over a two-year period since the initial treatments. There were rapid changes in dominance and invader species of understory vegetation for the burned, sewage dome than in any of the others. The duckweed layer is also thicker. The presence of sewage does not seem to have had an overriding influence in determining vegetation; however, the two sewage domes are less similar to one another in species composition than are the two burned domes. The similarity index for the species composition shortly after sewage introduction and one year later was 78 (possible maximum of 86) for the unburned dome, but only 62 for the burned dome, suggesting greater constancy for the flora in the second sewage dome in response to the stress of sewage. This suggests that the presence of nutrient vegetation at the time of sewage introduction has damped the kinds of changes in the unburned dome.

236. Ewel, K. C. 1976b. Effects of Sewage Effluent on Ecosystem Dynamics in Cypress Domes. pp. 169-196. In D. C. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of A National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

Studies of experimental treatment of cypress domes in Florida with wastewater are summarized. A dramatic seasonal increase was noted for three species of floating plants that were responsible for rapid uptake of heavy metals and nutrients. Large amounts of the nutrients subsequently were transferred to cypress roots after decay of the floating plants. Other changes in species composition also were noted. Tree growth and seedling growth were slightly faster in treated domes as compared with control domes. Litterfall was greater in the treated dome, but no differences in the decomposition rates of cypress needles were noted. (EPA)

237. Ewel, K. 1976c. Seasonal Changes in Distribution of Water Fern and Duckweed in Cypress Domes Receiving Sewage, pp. 164-170. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling and Conservation, Third Annual Report. Univ. of Florida, Gainesville.

During the spring, summer, and fall, the non-rooted, floating plant cover in two cypress domes which had been receiving secondarily treated sewage consisted almost entirely of two duckweed species, *Lemna perpusilla* and *Spirodela aligorhiza*. Small patches of *Azolla caroliniana*, a small floating water fern, was also found, usually associated with a patch of emergent vegetation. There were no floating plants on the surface of the central area of a cypress dome which has had groundwater pumped into it weekly, although both *Lemna* and *Azolla* are common around the edge. Only *Lemna* and *Spirodela* are found on the undisturbed dome. During the winter, *Azolla* increased its percentage in coverage in both domes significantly. This change may be due primarily to a change in light intensity. Considering both the nitrogen-fixing ability of *Azolla* and the dependence of *Lemana* on a nitrate source, the shift in species composition may clearly have important consequences on the nutrient cycling role played by the plants.

238. Ewel, K.C. 1979. Effects of Sewage Recycling on Structure and Function of Cypress Ecosystems. In: J.C. Sutherland and R.H. Kadlec (eds.), Freshwater Wetlands and Sanitary Wastewater Disposal. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI.

Cypress-dominated ecosystems are common in Florida and the Southeast in sites where standing water during part of the year reduces competition from other tree species, and occasional drawdowns permit germination.

Cypress domes, or ponds, have been found to be able to absorb nutrients from secondarily treated sewage applied at the rate of 2.5 cm/wk. This loading rate converts the oligotrophic cypress pond into a duckweed-covered, virtually anaerobic body of water. However, gross and net primary productivity rates are increased and decomposition rates are not affected. Under-story vegetation composition is not affected. Most of the phosphorus discharged into the cypress pond is apparently retained in the organic sediments and underlying clay layers.

Cypress strands, which are slowly flowing bodies of water dominated by cypress trees, area also being investigated for their potential in treating sewage because of the greater land area they cover. Examination of sites where sewage enrichment has occurred for forty years indicates that increased tree growth rates can be sustained. Investigations are underway to determine area needed for uptake of nutrients, heavy metals, and bacteria. (AA)

239. Ewel, K. C., and S. E. Bayley. 1976. Waldo, A Strand Receiving Sewage, pp. 759-767. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

240. Ewel, K. C., and H. T. Odum. 1978. Cypress Swamps for Nutrient Removal and Wastewater Recycling, pp. 181-198. In M. P. Wanielista and W. W. Eckenfelder, Jr. (eds.), Advances in Water and Wastewater Treatment: Biological Nutrient Removal. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.

This paper is an overview of research conducted on the effect of addition of sewage to cypress dome wetlands in Florida. This appears to be an ecologically and economically suitable method for tertiary treatment. Growth of cypress trees was increased greatly, but subcanopy vegetation was not altered to a similar degree. No increases in nitrogen or phosphorus in groundwater were observed. Also, no higher rate of export of encephalitis would be expected from a treated wetland, as opposed to a natural cypress swamp. The treatment method is considered to be economical because the "ratio of solar energy to dollar costs" is high.

241. Ewel, K. C., and H. T. Odum. 1979. Cypress Domes: Nature's Tertiary Treatment Filter, pp. 103-114. In W. E. Sopper and S. N. Kerr (eds.). Utilization of Municipal Sewage Effluent and Sludge on Forest and Disturbed Land. The Pennsylvania State University Press, University Park.

This paper is a summary of 4 years of research concerning the effects of additions of treated wastewater to cypress dome wetlands in northern Florida. It was concluded that these systems are capable of effective tertiary wastewater treatment. Domes are common in Florida, and the vegetation already is adapted to high water levels. The ability to deal with elevated nutrient loads is related to:

- A continuous cover of duckweed causing rapid nutrient removal;
- Uptake of nutrients deposited in sediments by duckweed and by cypress roots and incorporation in wood and leaves; trees may absorb up to 10% of the nutrient load;

- Phosphorus seems to adsorb on clays beneath the dome; the domes also appear to have an additional geological mechanism of precipitation of phosphate pebbles.

Overall, the ability of a dome to treat sewage is best evaluated by considering the "geologic framework within which the ecosystem operates," and "taking advantage of long-term adsorptive and concentrating properties." It is suggested that the use of domes for treatment of wastewater may be a viable alternative for small communities whose tax base is insufficient to support high-technology treatment systems.

242. Farnham, R.S. 1974. Use of Organic Soils for Wastewater Infiltration, pp. 111-118. In: A.R. Aandahl (ed.), Histosols: Their Characteristics, Use and Classification. Soil Sci. Soc. Am. Spec. Publ. No. 6.

243. Farnham, R.S., and D.H. Boelter. 1976. Minnesota's Peat Resources: Their Characteristics and Use in Sewage Treatment, Agriculture, and Energy, pp. 241-255. In: D.L. Tilton, R.H. Kadlec, C.J. Richardson (eds.), Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. University of Michigan, Ann Arbor.

Minnesota has 3 million ha (7.5 million acres) of peatlands, the most of any state in the conterminous United States. The most extensive areas of these peatlands are located in the large glacial lake plains in northern Minnesota. A few of the largest areas are vast expanses of peat ranging up to 200,000 ha in size and only a very small percent of them are presently being utilized for agriculture or forestry.

One of the more important resources of peatlands is water and the headwater areas for several major river basins are located in the northern forested regions of Minnesota on these peat-covered wetlands. The hydrologic role of peatlands may not be as significant as once thought. Rather than being giant sponges soaking up snowmelt and early spring rains and gradually releasing runoff through the summer, peatlands often play a less significant role in the seasonal distribution of runoff with a large portion of the annual flow occurring prior to June 15.

Drained and fertilized, these organic soils are productive for both field and forest crops. They are particularly suited to the production of vegetative crops, seed crops, forage crops, wild rice and other specialty crops although their present use for these crops is limited.

The unique physical properties of peat materials, especially Sphagnum types, suggest several potential uses for harvested peat. Their high water storage capacity and low density makes them very useful as a soil amendment to improve the physical properties of mineral soils or as a horticultural medium for plant growth. The relative high caloric values of peat have led to their use as fuel in Europe and similar potentials exist in Minnesota.

Peat materials have been used successfully as filter systems for treatment of campground sewage wastes in several national forests. Renovation of wastewaters is quite good using a combinatin of the filtering and absorbing action of the peat and the harvest of plants growing on the filter beds for assimilation and removal of nutrients. (AA)

244. Farnham, R.S., and J.L. Brown. 1972. Advanced Wastewater Treatment Using Organic and Inorganic Materials, Part I. Use of Peat and Peat-sand Filtration Media, pp. 271-286. In: Fourth Int. Peat Congr. Proc., Ontaniemi, Finland.

245. Ferrara, R.A., and D.R.F. Harleman. 1978. A Dynamic Nutrient Cycle Model for Waste Stabilization Ponds. Rept. No. 237 R78-43. Massachusetts Institute of Tech., Cambridge. 351 pp.

Stabilization ponds provide a simple, economic, and effective method of waste treatment. Due to their dynamic nature, there is a critical need for a reliable, predictive method for the design and analysis of stabilization ponds that goes beyond the classical BOD approach and considers biological and nutrient dynamics. Existing hydraulic models are evaluated and improved dispersion model characterized by an active flow zone and a return zone is developed and verified. It is shown it is appropriate to assume fully mixed conditions for most existing unbaffled ponds. A biogeochemical model containing nine state variables describing the transformations of three elements - carbon, nitrogen, and phosphorus - is developed. The model reflects the cycling of elements between organic and inorganic forms and is capable of predicting oxygen demand, fecal coliform, nitrogen, and phosphorus concentrations on a time-variable basis. Application of the model at existing treatment sites has indicated the capability of the model structure to adequately simulate the stabilization pond environment. (NT)

246. Fetter, C.W., and R.G. Holzmacher. 1974. Groundwater Recharge with Treated Sewage. J. Water Pollut. Control Fed. 46(2):260-270.

247. Fetter, C.W., Jr., W.E. Sloey, and F.L. Spangler. 1976a. Potential Replacement of Septic Tank Drain Fields by Artificial Marsh Wastewater Treatment Systems. Groundwater 14(6):396-402.

Unchlorinated primary effluent was applied to an artificial marsh in an experimental facility ay Seymour, Wisconsin (population 2,257), during the period 21 August to 4 November 1975. The marsh consisted of shallow trenches lined with PVC plastic and filled with gravel and handplanted specimens of bulrush (Scirpus validus). The vegetation and microbiota had been established previously during two seasons of experiments with secondary effluent. Effluent was applied at an average rate of 2.5 m^3/day, which yielded a loading factor of 29 l/m^2 and a retention time of about 10 days. Reductions in BOD_5 (77%), COD (71%), orthophosphate (35%), total phosphorus (37%), nitrate (22%), and coliform bacteria (99.9%) were reported. The researchers recommended the use of small-scale waste treatment systems at summer cottages, camping areas, resorts, and roadside rest areas where effluent would be applied only during the growing season. A proposed design for such a treatment system is included. (EPA)

248. Fetter, C. W., Jr., W. E. Sloey, and F. L. Spangler. 1976b. Wastewater Treatment by Natural and Artificial Marshes. U.S. National Technical Information Service. Pub. No. PB-259-992. Springfield, VA. 180 pp.

The feasibility of using marshland as a means of purifying sewage-works effluent was investigated, using artificial marshes in plastic-lined excavations, and a natural marsh in Wisconsin already receiving water polluted from a sewage-works outfall. The level of improvement in water quality suggests that the process may be acceptable for certain applications. Harvesting of vegetation, however, was not a practicable method of phosphorus removal since the marsh was found to absorb phosphorus during the growing season and to release it at other times. It is concluded that marsh treatment may be a practical means of dealing with temporary overloads of existing sewage-treatment systems during the summer. (AL)

249. Fetter, C. W., Jr., W. E. Sloey, and F. L. Spangler. 1977. Biogeochemical Studies of a Polluted Wisconsin Marsh, pp. 13-49. Proceedings of the First Annual Wisconsin Water Resources Conference, held 11 February 1977 at Stevens Point, WI.

250. Fetter, C. W., Jr., W. E. Sloey, and F. L. Spangler. 1978a. Biogeochemical Studies of a Polluted Wisconsin Marsh. J. Water Pollut. Control Fed.

This study concerns the effect of a Typha dominated marsh in Wisconsin on BOD, coliform bacteria, COD, nitrate, turbidity, suspended solids, total phosphorus, and orthophosphate. (WE)

251. Fetter, C. W., Jr., W. E. Sloey, and F. L. Spangler. 1978b. Use of a Natural Marsh for Wastewater Polishing. J. Water Pollut. Control Fed. 50(2): 290-307.

The water quality of a stream flowing through a Typha marsh was studied for a 15-month period. During low flow periods, as much as 50% of the wastewater monthly streamflow was discharge from a wastewater treatment plant. During passage through the marsh there were significant reductions in concentrations of biochemical oxygen demand (BOD) (80.1%), coliform bacteria (86.2%), nitrate (51.3%), chemical oxygen demand (43.7%), turbidity (43.5%), suspended solids (SS) (29.1%), total P (13.4%), and orthophosphate (6.4%). An estimated mass balance of P indicated the marsh might retain one-third of the entering P over an annual cycle. One source of P removal appears to be preciptation into the sediments. Because passage through a marsh will reduce the BOD, P, N and SS, discharged effluents may not necessarily need to meet strict water quality standards before entering the system. (AA)

252. Findlay, C. R. 1973. Salmonella in Sewage Sludge. Part II. Multiplication. Vet. Rec. 93:102-103.

253. Finn, J.T. and T.M. Leschine, 1980. Does Salt Marsh Fertilization Enhance Shellfish Production. An Application of Flow Analysis. Environmental Management 4(3):193-203.

Flow analysis was used to determine that adding nitrogen fertilizer to Spartina salt marsh sediment was not an efficient way to enhace shellfish growth. Nitrogen flow models for Barataria Bay salt marsh, Louisiana, and Sippewissett Marsh, Cape Cod, indicated that in both locations only 3% of added N reached the shellfish, despite the great physical differences and despite the inclusion of considerably more microbial processing of N in the Barataria Bay model. The most efficient N transfer would have to bypass Spartina growth, decomposition, and detrital feeding.

254. Fitzgerald, M. G. 1980. Anthropogenic Influence on the Sedimentary Regime of an Urban Estuary-Boston Harbor. Ph.D. Diss. Dept. of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA. 300 pp. (Available as Woods Hole Oceanographic Inst. Rept. No. 80-38.)

Boston Harbor (and its approaches) is a glacially carved, tidally dominated estuary in western Massachusetts Bay. Characterized by low river discharge and significant human impact, the harbor is typical of many bays and estuaries along the New England coast. Modern organic-rich sediments are accumlating in several depocenters at an estimated rate of 0.2-0.3 cm/yr. The high organic matter content of these modern sediments is attributed in part to anthropogenic wastes. Wastes rich in trace metals are discharged into the harbor from the sewage treatment facility at Deer Island and from numerous point sources in the Inner Harbor. Trace metal profiles in the bottom sediments reflect the increasing use and discharge of these metals during the past 100 years. Large variations in several cores may be related to circulation changes. In the water column, silt and clay sized mineral grains are suspended together in organically bound agglomerates. The organic film binding these particles is a by-product of biological activity and aids in the deposition of particulates and pollutants. (NT)

255. Fitzgerald, P.R. 1981. Helminth and Heavy Metals Transmission for Anaerobically Digested Sewage Sludge. Pub. No. EPA-600/S2-81-924. U.S. Environmental Protection Agency. Cincinnati, OH.

This summary discusses the findings of a study designed to determine the transmission to an animal host of the ova of the nematode worm Ascaris sp. that have survived through a modern sewage treatment process and are present in the sludge. Four large experiments and three smaller ones involving 178 specific pathogen-free (SPF) pigs were used. Natural transmission of Ascaris sp. from soil treated with liquid anaerobically digested sewage sludge that had been stored for several years occurred in a few pigs in each of four experiments. Also, natural transmission from Nu-Earth, a dried, stored sewage sludge, also occurred in pigs that were exposed to this material by contact in the pens. In general, ova in anaerobically digested sludge or in Nu-Earth remained unembryonated until after they were exposed to the air. Within 6 weeks after exposure to air, the ova began to embryonate, and thereafter, a small percentage of the ova that embryonated became infective for pigs.

The occurrence of heavy metals in the tissues of swine held in pens treated with anaerobically digested sludge or Nu-Earth, which originated from a large municipality, was also studied. Chemical analyses of kidneys, livers, hearts, diaphragm muscles, and bones were conducted to determine the quantities of the heavy metals cadmium, zinc, copper, iron lead, chromium, and nickel that were present in the tissues following exposure of the pigs to different amounts of the sewage products in or on the soil. Only cadmium accumulated to a significant degree in some tissues of swine exposed to sludge containing heavy metals. No physiological or pathological changes associated with exposure to the sludge material were detected. Examination of visceral fat from control and experimental pigs indicated that there was no unusual accumulation of organic compounds including polychlorinated biphenyls (PCB's) and the insecticides Heptachlor and Dieldrin.

256. Flemer, D.A. and D.R. Heinle. 1974. Effects of Wastewater on Estuarine Ecosystems. Publication 33. Chesapeake Research Consortium, Inc., Baltimore, MD. 33 pp. (Also published as Maryland Univ. (Solomons) Natural Resources Inst. Ref. No. 74-79.

Recent increases in algae, measured as concentration of chlorophyll a, in the Patuxent River estuary appear to have occurred as a consequence of increased loading by sewage in the upper watershed. The increases in concentration of chlorophyll were observed downstream from the turbid sediment-trap portion of the estuary, an impact distant from the points of addition. Primary production, measured by the 14C method, increased also as did zooplankton biomass. Samples of water from the Sandy Point area of the upper Chesapeake Bay were enclosed in 750-liter (200 gallon) polyethylene microcosms, enriched with treated sewage, and ensuing events followed. While the predictions from the microcosms have been fully validated, clear effects on several parameters were noted. Phosphate appeared to be the major limiting nutrient in these experiments. Enriched microcosms developed higher concentrations of zooplankton and chlorophyll a and rates of primary production, permitting predictions of effects of the sewage treatment plant under various loads. (NT)

257. Folsom, B. L., Jr., C. R. Lee, and D. J. Bates. 1980. Influence of Disposal Environment on Availability and Plant Uptake of Heavy Metals in Dredged Material. Tech. Rept. U. S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

258. Fox, J. C., and P. R. Fitzgerald. 1979. The Presence of Giardia lamblia Cysts in Sewage and Sewage Sludges from the Chicago Area. In W. Jakubowski and J. C. Huff (eds.), Waterborne Transmission of Giardiasis. EPA-600/9-79-001, U.S. Environmental Protection Agency, Cincinnati, OH.

259. Fox, R. L., and E. J. Kamprath. 1971. Adsorption and Leaching of P in Acid Organic Soils and High Organic Matter Sand. Soil Sci. Soc. Amer. Proc. 35:154-156.

260. Frederickson, L. 1978. Lowland Hardwood Wetlands: Current Status and Habitat Values for Wildlife. pp. 296-306, In: P.E. Greeson, J.R. Clark, and J.K. Clark (eds.), Wetland Function and Values - The State of our Understanding. Proceedings of the National Symposium on Wetlands, Buena Vista, Florida. Amer. Water Resources Assoc. 7-10 November 1978.

261. Friend, Milton. In press. Wildlife Health Implications of Sewage Disposal in Wetlands. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a workshop, June 23-25, 1982. University of Massachusetts, Amherst MA. US Fish and Wildlife Service and US Environmental Protection Agency.

262. Fritz, W. R., and S. C. Helle. 1977. Tertiary Treatment of Wastewater Using Cypress Wetlands. National Science Foundation. Updated Preliminary Envir. Rept. 76-23276. 96 pp.

This report deals with the results of study using cypress domes for tertiary treatment of secondary effluent. Conclusions include: 1) cost comparisons with physical, chemical, spray irrigation and other wetland treatment methods show cypress domes to be cost effective if favorable site specific conditions exist, 2) feasible loading rates and physical size of domes restrict applicability to small wastewater systems, and 3) analysis reveals that wetland treatment required substantially less purchased energy and chemicals. No significant detrimental effects to dome ecology have been discovered. (WE)

263. Fritz, W. R., and S. C. Helle. 1978a. Cypress Wetlands as a Natural Tertiary Treatment Method for Secondary Effluents. Boyle Engineering Corp., Orlando, FL. National Science Foundation Summary Rept. 14 pp.

The concept of using cypress wetlands as a natural tertiary treatment mechanism for domestic wastewaters is examined. Previous studies have shown that cypress domes supplied with sewage effluent effectively treated the effluent well within acceptable tertiary treatment standards with no significant adverse effect on the environment. As a result of these findings, a three-phase approach was developed for an applied engineering science suitable for implementation. This article addresses Phases 1 and 2: development of conceptual techniques for using cypress wetlands for tertiary treatment and determination of the feasibility of utilizing the method. (NT)

264. Fritz, W. R., and S. C. Helle. 1978b. Cypress Wetlands as a Natural Treatment Method for Secondary Effluents, pp. 69-81. In M. A. Drew, (ed.), Environmental Quality through Wetlands Utilization. Proceedings of a symposium held 28 February - 2 March 1978, at Tallahassee, FL. Sponsored by the Coordinating Council on the Restoration of the Kissimmee River Valley and the Taylor Creek-Nubbin Slough Basin. Tallahassee, FL.

Research by the Center for Wetlands, University of Florida demonstrates that cypress wetlands can be a natural tertiary treatment mechanism for domestic wastewaters. Their studies show that wetlands provide excellent nutrient removal with no significant adverse environmental effects. Boyle Engineering Corporation has been awarded a National Science Foundation grant to study the research and convert it into an applied engineering science. Boyle's approach has been to: 1) examine the various concepts of using cypress wetlands for tertiary treatment, 2) explore the feasibility of each concept, and 3) develop procedures and preliminary regulations for implementation.

Thus far, the study has demonstrated that cypress wetlands offer a viable tertiary treatment alternative for many potential users. The research to date has concentrated on using isolated cypress "domes" involving ponding and percolation of wastewaters. The treatment results, reliability, energy conservation potential, and environmental outlook for the method are quite favorable. Federal and state regulatory agencies cautiously support wetland treatment systems, allowing demonstration projects, but are not yet ready to permit widespread implementation. Cost analyses have shown cypress domes to be cost competitive if the wetlands are favorably located. A survey of treatment plant locations with adequate cypress wetlands is being conducted to determine the availability of application throughout the State of Florida. (AA)

265. Fritz, W. R., and S. C. Helle. 1978c. Cypress Wetlands for Tertiary Treatment. Boyle Engineering Corp., Orlando, FL. National Science Foundation Final Report. 114 pp.

The report contains a summary of studies of impacts on vegetation in cypress domes that receive wastewater. In general, cypress trees appear to suffer little negative effects, and in fact may even grow more rapidly (in one study they grew 2.6 times as fast). Other studies have shown that needle tissue levels of N and P and seed production increased as a result of wastewater application. Possible negative effects could include the requirement of cypress seedlings for periodic dry periods for germination. Other impacts on vegetation include increased abundance of duckweed, associated with nutrient and heavy metal uptake by those plants. Cypress roots may absorb a large percentage of nutrients when the duckweed dies off. Other impacts include creation of anaerobic conditions during duckweed population declines and possible changes in denitrification rates, but these have been determined not to cause significant changes in the ecology of the domes. (EPA)

266. Fritz, W. R., and S. C. Helle. 1978d. Tertiary Treatment of Wastewater Using Cypress Wetlands. Boyle Engineering Corp., Orlando, FL. National Science Foundation Final Report No. 0-N04-100-50. 114 pp.

Intense field investigation, testing, and research were conducted for the purpose of providing tertiary treatment utilizing cypress domes. Presented in four annual reports, the research has demonstrated high quality treatment using cypress domes, while recycling water and helping to protect the environment from periodic drought conditions. Treatment concepts and results, cost-effectiveness, energy and environmental considerations, reliability, regulatory agency aspects, availability, and a proposed rule for application of domestic wastewater to cypress wetlands are discussed. Also included are considerations for an engineering design of a cypress wetland tertiary treatment system and the dissemination of information through seminars and conferences, publications, workshop, and reports. (NT)

267. Fritz, W. R., and S. C. Helle. 1979a. Cypress Wetlands for Tertiary Treatment, pp. 75-81. In Bastian, R. K., and S. C. Reed (Project officers). Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, D.C.

268. Fritz, W. R., and S. C. Helle. 1979b. Cypress Wetlands: A Natural Tertiary Treatment Alternative. Water and Sewage Works 126(4):58-60.

269. Fritz, W. R., and S. C. Helle. 1979c. Natural Tertiary Treatment of Secondary Effluents by Wetlands in Florida. In: J.C. Sutherland and R.H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI.

In Florida, two forms of cypress wetlands are found to be suitable for tertiary treatment. Cypress domes are relatively small (1-25 acres) wooded ponds which collect runoff from surrounding higher grounds and allow it to percolate slowly into underlying soils and groundwaters. A strand is a diffuse freshwater stream flowing through a shallow cypress forested depression on a gently sloping plain.

The Center for Wetlands' research has demonstrated that cypress domes offer a viable tertiary treatment alternative for many potential users. A demonstration project using cypress domes attained 98% total nitrogen and 97% total phosphorus removal. The concentrations of the nutrients, coliforms, viruses, heavy metals and other monitored parameters in the groundwaters remained virtually unchanged from background levels. However, an investigation by Boyle Engineering Corporation also revealed that these ponding and percolation wetland systems are limited by their physical size and availability.

A survey of nearly one-half the wastewater treatment facilities in Florida showed that while only 3% of the state's wastewater effluent had the potential of being treated with cypress domes, over 28% of the effluent had the potential of being treated with cypress strands and other flow-through forested wetlands. Thus, it becomes apparent that flow-through systems offer more promise for use and should be investigated further.

Two and one-half years of research and testing (to quantify design parameters) will be conducted in conjunction with the Center for Wetlands at two wetland sites near Jasper and Waldo, Florida. In both instances, municipal treatment plants discharge secondary effluents into wetlands.

A number of water quality and vegetation response parameters are being monitored and analyzed at several locations within the study and control areas. Among the water quality parameters being studied are nutrients, heavy metals, and coliform bacteria. Vegetation analyses will include determination of tree growth rates, litterfall rates and study of successional changes occurring in the vegetation. Very early results indicate that phosphorus is not removed from the wastewater as rapidly as nitrogen and thus may be the controlling factor. (AA)

270. Fritz, W. R., and S. C. Helle. 1980a. Tertiary Treatment of Wastewater Using Flow-Through Wetland Systems, Status Report 3. Boyle Engineering Corp., Orlando, FL. 79 pp.

The monitoring operations and a water budget analysis of a flow-through wetland system for wastewater treatment near Jasper, FL, named Basin Swamp are evaluated. The purpose of the monitoring program is to identify the effects of wastewater on the swamp as well as the effects of the swamp on wastewater effluent. In addition, points where the magnitude of these effects diminish to background levels are being identified. An effort is being made to determine which effects are acceptable to the wetland environment and public health. Monitoring of surface and subsurface waters included studying water chemistry, nutrients, heavy metals, vegetation, and coliform bacteria. Preliminary results show: 1) a reduction of total nitrogen to near background levels; 2) a reduction of phosphorus levels; 3) that the application of effluent to cypress strand may be harmful to trees; 4) that the total and fecal coliform levels appear to be readily reduced; 5) that nutrients and coliform bacteria penetrate shallow groundwater levels; and 6) that no significant amounts of heavy metals are being applied to Basin Swamp. To supplement various monitoring programs, a water budget analysis was refined and updated to include data collected from weekly monitoring operations. Results significantly improved the accuracy of the water budget analysis. (NT)

271. Fritz, W. R., and S. C. Helle. 1980b. Tertiary Treatment of Wastewater Using Flow Through Wetland Systems, Status Rept. 2. Boyle Engineering Corp., Orlando, FL. 115 pp.

Recent research has demonstrated that certain types of wetlands can provide tertiary treatment for effluents from secondary wastewater treatment facilities. To identify and quantify design parameters for implementing such systems, a study is being conducted at a north Florida site near Jasper. This report describes the development of the monitoring system and its preliminary mapping. It presents a brief history of the project, the study approach, the research plan, preliminary results, and recommendations for monitoring future periods. Reports for each of five monitoring programs are included in the appendices: water chemistry; bacterial sampling; vegetation distribution in West Swamp; and an analysis of cypress tree growth rate. The appendices also include research on a water budget study, development of a water budget model, instructions for a water monitoring program, and output from a water budget program. Findings indicate that nitrogen appears to be removed to below AWT levels with a loading rate of about 100 acres per mgd. Phosphorus is not removed as readily. Applying raw and/or primary effluent to a cypress stand appears to be harmful to the trees whereas applying secondary effluent appears to be beneficial. (NT)

272. Frook, D. S. 1974. Clarification of Sewage Treatment Plant Effluent with *Daphnia pulex*. Master's Thesis. Univ. of Toledo. OH.

273. Frykberg, W. R., C. J. Goodnight, and P. G. Meier. 1975. Limnological Investigation of the Muskegon County, Michigan, Wastewater Storage Lagoons. Phase 1. EPA/600/3-75-009. U.S. Environmental Protection Agency, Interim Rept.

The limnology of two 850 acre wastewater storage lagoons was investigated from September 1973, shortly after the initial filling, through August 1974. Special emphasis was placed upon the biological aspects of these lagoons. During the period of study, the East Lagoon received most of the wastewater, while the West Lagoon received mostly land drainage and seepage water. Due to these different waters in each lagoon, differences in most of the parameters were apparent between the two lagoons. Chironomid larvae comprised virtually all of a scant benthic population in both lagoons, with different dominant genera in each body of water. The dominant zooplankton in the East Lagoon were cyclopoid copepods, with *Cyclops vernalis* the most common form, while calanoid copepods and *Daphnia* were dominant in the West Lagoon. Chlorophyll a and primary productivity were measured and numerous physical-chemical parameters were also investigated. (NT)

274. Frykberg, W. R., C. Goodnight, and P. G. Meier. 1977. Muskegon, Michigan Industrial-Municipal Wastewater Storage Lagoons: Biota and Environment. U.S. Environmental Protection Agency, Final Rept. EPA/600/3-77-039. 89 pp.

A limnological investigation was carried out on two 344 hectare (850 acre) industrial-municipal wastewater storage lagoons from August 1973 until August 1975. Besides monitoring physical and chemical parameters during the period of the initial filling, the biological community was critically examined for the purpose of documenting ecological succession over this two year period. In general, the lagoons remained aerobic, well mixed vertically, and slightly alkaline. The low transparency within the lagoons was an important factor which limited the phytoplankton population and excluded rooted aquatics and benthic algae. Ample nutrients were present for algal demands. The lagoon's phytoplankton-protozoan assemblage was extremely variable with respect to total abundance distribution. The zooplankton community was composed of fourteen species of free living crustaceans and four species of rotifers. The benthic fauna consisted of a small number of organisms representing only a few taxonomic groups. (NT)

275. Fuller, R.J., and D.E. Glue. 1980. Sewage Works as Bird Habitats in Britain. British Trust for Ornithology, United Kingdom. Biological Conservation 17(3):165-182

This research report demonstrates that sewage treatment works are essentially good bird habitats. Bird communities associated with different sewage disposal systems in the United Kingdom are described in relation to the components of each system. Ornithological gains and losses associated with recent developments in sewage treatment methods are discussed. Modern sewage treatment works, which are smaller in area than sewage farms, support smaller and less varied populations of wetland species. However, modern sewage treatment works can be important bird habitats, particularly as feeding sites for several passerine species. Systems with percolating filters and tertiary treatment by surface irrigation will support the most varied bird communities. (EPA)

276. Fuller, R.J. and D.E. Glue, 1981. The Impact on Bird Communities of the Modernization of Sewage Treatment Works. Effluent and Water Treatment Journal 21(1):27-31.

The main ornithological characteristics of the obsolete sewage farms in Great Britain are described, and the ornithological potential of modern sewage works is discussed. Sewage treatment systems in Great Britain have provided some of the most spectacular examples of birds utilizing human artifacts.

277. Gallagher, J. L. 1978. Decomposition Processes: Summary and Recommendations, pp. 145-151. In R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, Inc., New York, NY.

278. Gallagher, J. L., and H. U. Kibby. 1980. Marsh Plants as Vectors in Trace Metal Transport in Oregon Tidal Marshes. Am. J. of Bot. 67(7):

279. Gambrell, R.P. 1977. Transportation of Heavy Metals and Plant Nutrients in Dredged Internal Sediments as Affected by Oxidation Reduction Potential pH; Volume II, Materials and Methods/Results and Discussion. Contract Rept. D-77-4.

280. Gambrell, R. P., V. R. Collard, C. N. Reddy, and W. H. Patrick, Jr. 1977. Trace and Toxic Metal Uptake by Marsh Plants as Affected by Eh, pH, and Salinity. U.S. Army Corps of Engineers, Waterways Experiment Station, Dredged Material Research Program Technical Rept. D-77-40.

A laboratory study was conducted to develop and refine methods for growing marsh plants under conditions of controlled pH, redox potential (oxidation-reduction conditions) and salinity as well as to determine the effects of these physiochemical conditions in the rooting medium on trace and toxic metal availability to plants. Reasonably successful methods were developed for growing marsh plants in the experimental systems. The successful methods as well as procedures which were not successful are discussed as are techniques for overcoming many of the experimental difficulties.

In laboratory studies using soil suspensions, *Distichlis spicata* (L.) Greene, *Spartina alterniflora* Loisel, and *Spartina cynosuroides* (L.) Roth were grown in soil suspensions in which treatments included oxidized and reduced conditions at two pH levels and two salinity levels. The effect of these soil physiochemical conditions on plant content of mercury, lead, cadmium, copper, iron, and manganese was studied. Lead and cadmium uptake by *Oryza sativa* L. was also studied, but over a range of four soil pH levels and six redox (oxidation-reduction) potential conditions.

Greenhouse studies were conducted using *Distichlis spicata*, *Spartina alterniflora*, and *Sorghum halepense* (L.) Pers. in which oxidation-reduction conditions were controlled in unstirred soil material. The plant content of the trace metals studied in the greenhouse generally supported results of laboratory studies where soil suspensions were used as the rooting medium.

In laboratory studies using labeled mercury, the content of this metal in marsh plants tended to be enhanced by decreases in salinity and increases in pH.

Although results with lead were inconclusive in laboratory studies, lead uptake by lowland rice was enhanced as the soil became more acid. In greenhouse studies, an increase in soil oxidation-reduction conditions increased plant lead content, but this was attributed to a redox potential mediated effect on soil pH.

Plant cadmium content responded more to a change in the physiochemical environment of the rooting medium than did other metals studied. The cadmium content of above ground tissue was consistently and substantially increased with an increase in oxidation conditions in all species in both laboratory and greenhouse studies. Maximum cadmium content occurred under acid, oxidizing conditions except for one species in which an oxidized, weakly alkaline environment favored increased cadmium content.

The effects of physiochemical conditions on the zinc content of plants grown in the greenhouse were studied where the zinc content was found to increase with increasing oxidation conditions.

There was little effect of either pH or oxidation-reduction conditions on the copper content of the species studied.

Two extractants were used on the soil suspensions following harvest to determine the linear relationships between chemical availability and plant content of metals in laboratory studies. Of the metals studied, cadmium generally gave the best linear association between measured uptake and chemical availability, although there were important species differences. Based on the results of this research, it was concluded that soil and sediment physiochemical conditions do affect the plant availability of trace and toxic metals, and it was recommended that these effects should be considered in selecting environmentally sound disposal methods for contaminated dredged sediments. (AA)

281. Garbisch, E. W., Jr. 1977. Recent and Planned Marsh Establishment Work Throughout the Contiguous United States - A Survey and Basic Guidelines, U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Rept. D-77-3. Vicksburg, MS.

282. Garbisch, E. W., Jr. 1978. Wetland Rehabilitation, pp. 217-219. In J. H. Montanari, and J. A. Kusler (eds.), Proceedings of the National Wetland Protection Symposium held 6-8 June 1977 at Reston, Virginia. FWS/OBS-78/97. U.S. Fish and Wildlife Service, Washington, DC.

283. Gaudet, J.J. 1978. Effect of a Tropical Swamp on Water Quality. Verhandlungen Internationale Veremiging Fur Theoretische und Unvewandte Limnologie. (20(4):2202-2206

A papyrus swamp may be effective in removal of organic nutrients from sewage effluents directed into these swamps, but will have little effect on the salt content of the effluent if the discharge is at a high rate. Water samples collected from a floating papyrus swamp show a decrease in major ions on the swamp bottom during the period August-December. Papyrus takes up and accumulates considerable amounts of the major ions.

284. Gearheart, R. A., and B. A. Finney. 1981. Use of Vascular Plants for Treatment and Reclamation of Oxidation Pond Effluent and Non-Point Source Pollution Loads. Presented at the Water Reuse Symposium II. Washington, DC. August 23-28, 1981.

The City of Arcata is presently funding an alternative wastewater pilot project by the State Water Resources Control Board, which will 1) evaluate the feasibility of using secondarily treated wastewater to enhance the productivity of a freshwater marsh, and 2) to test the effectiveness of marshes to reliably treat stabilization pond effluent to tertiary standards. Twelve 0.11 acre (22 feet by 200 feet) experimental marshes have been operated with varying flow rates, types and density of vegetation, and depth of flow. The experimental design requires testing and evaluation of the optimum aquatic composition, water level control, hydraulic toading rate, organic and nutrient loading rates, and management practices for use as a wastewater reclamation process. Nutrients such as ammonia nitrogen, Kjeldahl nitrogen, nitrates, nitrites, and phosphate forms as well as other water quality parameters such as BOD, COD, total and fecal coliform, and fecal streptococcus. A balance of the bio-mass production and its associated nitrogen content will be made. A thorough sampling program of the aquatic plants, including roots and rhizomes, phytoplankton, zooplankton, heavy metals, pH, temperature, and specific conductivity have been monitored on a regular basis.

The City of Arcata has also constructed three marshes, adjacent to the existing wastewater treatment facility, totaling 35 acres, and a 17-acre recreational lake all connected in series with hydraulic alternatives to isolate any one of the three marshes from the total system. The water source for this study area will be obtained from James Creek and from a well on site for use during dry periods. One of the water quality objectives of this project is to reduce the non-point source load to Humboldt Bay by processing the runoff through wetland systems. This project, referred to as the City of Arcata's Coastal Conservancy Marsh Enhancement Project, involves the restoration and enhancement of 35 acres of freshwater marsh and conversion of a sterile catch basin and a closed-out sanitary landfill into a recreational lake would restore approximately seventeen acres to a productive aquatic habitat and the landfill conversion, once implemented, would add ten acres to the entire project.

The marsh system and recreational lake are designed as a series of units so that continuous and uninterrupted productivity of the aquatic systems will be possible at all times. The input flow to the Marsh Enhancement Project will be from James Creek watershed (combined agricultural and urban non-point sources of pollution) during the wet months of the year and from a well with relatively high water quality during the dry months of the year where low flow augmentation precludes taking water from James Creek. (AA)

285. Gee & Jenson Engineers, 1980. Water Hyacinth Wastewater Treatment Design Manual. NASA/National Space Technology Laboratories. NSTL Station, Mississippi.

This handbook on wastewater treatment with water hyacinths has been prepared with two objectives in mind. The primary objective is to present practical procedures necessary to plan, design and construct a wastewater treatment system utilizing water hyacinths. Laboratory and field-scale investigations have repeatedly demonstrated that wastewater treatment with water hyacinths can be a viable, cost-effective alternative to conventional treatment schemes. The state-of-the-art has reached a level where existing data can be used to develop reliable design requirements and procedures, as presented in this manual.

A secondary objective is to provide a reference on water hyacinths that can be used by engineers, designers, researchers, city officials, utility personnel, public regulatory agencies and others involved in wastewater treatment systems. A concise summary of past research is presented so interested individuals can locate information pertaining to their needs. (AA).

286. George, D.B., 1981. Lagoons and Oxidation Ponds. J. Water Pollut. Cont. Fed. (Literature Review Issue), 53(6):709-711.

A literature review is presented of publications on lagoons and oxidation ponds published in 1980. Articles fall into the general categories of process performance and biology, upgrading of lagoons, and process models. Connecticut published standards on lagoon systems for the disposal of septage. Several studies dealt with the Dan Region Project, which is the largest and most advanced water reuse scheme in Israel which utilizes oxidation ponds. A study on stabilization ponds in Peru examined the use of treated wastewater for agricultural purposes. More stringent wastewater treatment plant discharge standards resulted in several studies on upgrading existing lagoons. An in situ method is alum addition, another study investigated water hyacinth, and another evaluated the culturing of fathead minnows. Process models included a biogeochemical model developed to describe the dynamic responses of carbon, nitrogen, phosphorus, and pathogenic contaminants in facultative wastewater stabilization ponds.

287. Giblin, A. E., A. Bourg, I. Valiela, and J. M. Teal. 1980. Uptake and Losses of Heavy Metals in Sewage Sludge by a New England Salt Marsh. Am. J. Bot. 67(7):1059-1068.

As part of an investigation on the potential of salt marshes to act as natural waste treatment systems, the cycling of heavy metals in Great Sippewissett Marsh, MA, was studied. For the last 7 yrs., varying doses of fertilizer containing sewage sludge were added to experimental plots. Changes in metal levels in the sediment, grasses, and animals were monitored. Marsh sediments retained 20-35% Cd, 20-50% Cr, 60-100% Cu, 55-100% Pb, 80-100% Fe, 55-60% Mn and 20-45% of the Zn added in the fertilizer. When compared with low marsh, high marsh areas retained a significantly greater fraction of all the added metals except Mn. In the treated plots the dominant grasses, Spartina alterniflora and S. patens, contained elevated levels of Cd, Cr, Cu and Zn. Recent Spartina litter contained elevated levels of Fe, Cu, Cr, and Pb and reduced levels of Cd. The mussell Modiolus demissus exhibited significantly elevated levels of Cd, Cr and Cu and reduced levels of Pb compared to control animals. The fiddler crab Uca pugnax showed significantly higher levels of Cd, Cu, and Mn. (BA)

288. Giesecke, F. E., and P. Zeller. 1939. Treatment of Settled Sewage in Lakes. Bulletin 47, Agricultural and Mechanical College, Texas A & M Univ. College Station.

289. Gloyna, E. F., J. F. Malina, Jr., and E. M. Davis. 1976. Ponds as a Wastewater Treatment Alternative. Water Resources Symp. #9. Center for Water Research, College of Engineering, Univ. of Texas, Austin. 447 pp.

290. Goldman, J. C. 1979. Outdoor Algal Mass Cultures. I. Applications. Water Research 13(1):1-19.

Giving a bibliography of 111 references, the author reviews work on the mass culture of algae, with particular reference to the relative merits of existing and new applications, including production of single-cell protein, aquaculture, sewage treatment, and water renovation. (AL)

291. Goldman, J. C. et al. 1974. Inorganic Nitrogen Removal in a Combined Tertiary Treatment-marine Aquaculture System I. Removal Efficiencies. Water Res. 8:45-54.

292. Goldman, J. C., and J. H. Ryther. 1975. Nutrient Transformations in Mass Cultures of Marine Algae. J. Env. Eng. Div., ASCE 101:351-364.

Results from the continuous operation of 2 algal growth ponds containing mixtures of secondary sewage effluent and sea water, over a period of 24 weeks, demonstrated the feasibility of this method for nutrient removal from wastewater and/or food production for aquaculture of shellfish. Nitrogen removal was highly dependent on operating conditions and graphs show the effects of dilution rate and nitrogen loading on nitrogen removal and algal growth. Removal of nitrogen, through evolution of ammonia at the high pH values attained in the ponds, was enhanced by maintaining ammonium nitrogen as the dominant form in the sewage effluent. Algal yields of 6 g of particulate carbon/m^2/day we obtained. A bibliography of 22 references is appended. (AL)

293. Goldman, J. C., and J. H. Ryther. 1976a. Development of a Waste Recycling Marine Aquaculture System. In J. Tourbier and R. W. Pierson (eds.), Biological Control of Water Pollution. The University Press, Philadelphia, PA.

294. Goldman, J. C., and J. H. Ryther. 1976b. Waste Reclamation in an Integrated Food Chain System, pp. 197-214. In J. Tourbier and R. W. Pierson (eds.), Biological Control of Water Pollution. Univ. of Pennsylvania. Philadelphia. re

295. Goldman, J. C., K. R. Tenore, J.H. Ryther, and N. Corwin. 1974. Inorganic Nitrogen Removal in a Combined Tertiary Treatment Marine Aquaculture System. I. Removal Efficiencies. Water Resources 8:45-54.

The increasing awareness that nitrogen is often a key nutrient controlling algal growth in coastal maring waters has led to a concerted effort to find ways to remove ammonia and nitrate from wastewaters. A novel approach to this problem involves the combining of algal and seaweed nutrient stripping processes with a marine aquaculture. Not only is nitrogen removed from wastewater, but important commercial shellfish and seaweeds are produced.

A prototype process consisting of growth systems for marine algae, oysters, and seaweed, joined in series was fed secondarily treated wastewater, diluted 1:4 with seawater for 11 weeks during the Summer of 1972. During this time 95 percent of the influent inorganic nitrogen was removed by algal assimilation. The oysters in turn removed 85 percent of the algae, but regenerated as soluble ammonia 16-18 percent of the nitrogen originally bound in the algal cells. All of the regenerated nitrogen was removed in the seaweed system so that the total inorganic nitrogen removal efficiency of the system was 95 percent. Phosphorus removal on the other hand, was not nearly as complete as only 45-60 percent was removed.

The process has the capability of being expanded to include additional trophic levels in an integrated and highly controlled food chain system to serve the dual function of tertiary wastewater treatment and waste recycling through the production of shellfish and seaweeds. (AA)

296. Goldman, J. C., K. R. Tenore, and H. I. Stanley. 1974. Inorganic Nitrogen Removal in a Combined Tertiary Treatment - Marine Aquaculture System. II. Algal Bio-assays. Water Res. 8:55-59.

Algal bio-assays of samples from the mariculture sewage treatment system showed that seawater dilutions of sewage effluent from which nitrogen had been removed, supported no more algal growth than sea water alone. Samples from the oyster culture tank contained regenerated nitrogen and showed increased algal growth potential, but assays of the effluent from the seaweed growth stage confirmed that this regenerated nitrogen had been removed.

297. Golueke, C.G. 1979. Aquaculture in Resource Recovery. Compost Science/Land Utilization, 20(3):16-23.

298. Golueke, C. G., and L. F. Diaz. 1981. Operating a Solar Aquaculture Sewage Treatment Plant. Biocycle 22(1):38-39.

Hercules, CA, is a rapidly growing community with a rapidly growing sewage treatment problem. In an experiment that could have important implications for the future of sewage treatment in Hercules and other growing communities, about 25-50% of the city's wastewater is currently diverted to a solar aquaculture facility, where water hyacinths and other biological agents stabilize the dissolved and suspended solids in wastewater. Principle elements of the facility are a primary tank, an aeration basin, and a water hyacinth lagoon. Problems that have developed during five months of operation are discussed. (EL)

299. Golueke, C. G., and W. J. Oswald. 1965. Harvesting and Processing Sewage-grown Planktonic Algae. J. of Water Pollu. Control Fed. 37:471-99.

The great unit savings which would result from the production and separation of algae in large plants should encourage neighboring communities to merge their sewage flows and pump the material to areas of inexpensive level land. Here, large, skillfully managed systems could be used for converting waste nutrients to algae at low unit costs.

The entire question resolves itself to a final one of whether or not there is a durable and lucrative market for sewage-grown algae. Should such a market exist, communities which are forced by rigid water pollution control requirements to undertake tertiary treatment could ill-afford to overlook algae production as an early and ultimate step in their waste disposal systems. (AA).

300. Good, R. E., D. F. Whigham, and R. L. Simpson (eds.). 1978. Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, New York, NY. 378 pp.

Proceedings of the symposium, "Freshwater Marshes: Present Status, Future Needs," held in February 1977 at Rutgers University, New Brunswick, NJ. Contains six articles on primary production processes, five on decomposition processes, six on nutrient dynamics, and six on management potential.

301. Gordon, M.S., and D.J. Chapman. 1979. Aquaculture Approaches to Wastewater Nutrient Recycling. Technical Completion Report. Office of Water Research and Technology, Washington, DC. 79 pp.

Five years of laboratory scale studies were conducted to assess the potential of wastewater aquaculture as a means of 1) developing a basis for a freshwater aquaculture industry in the U.S., 2) producing salable foods or other commodities to improve waste treatment plant economics, 3) reducing agricultural energy costs by eliminating fertilization needs, and 4) improving the quality of waste treatment plant discharges. Sequential monocultures of wastewater based food chains were investigated using algae, crustaceans, and fishes. All wastewater used for the studies was fully secondarily treated, chlorinated, and dechlorinated. Results show that the use of artificial food chains for tertiary wastewater treatment is feasible for the reduction of nutrient loading and for the production of valuable protein sources. (NT)

1072. Gosselink, J.G. and L. Gosselink. In press.

302. Gosselink, J. G., E. P. Odum, and R. M. Pope. 1974. The Values of the Tidal Marsh. Sea Grant Publ. LSU-SG-74-03. Center for Wetland Resources, Louisiana State Univ., Baton Rouge. 30 pp.

303. Goulden, C. E. 1976. Biological Species Interaction and Their Significance in Waste Stabilization Lagoons. In Ponds as a Wastewater Treatment Alternative. Water Resources Symp. #9. Center for Water Research, College of Engineering, Univ. of Texas. Austin.

304. Goulder, R., A. S. Blanchard, P. L. Sanderson, and B. Wright. 1980. Relationships Between Heterotrophic Bacteria and Pollution in an Industrialized Estuary. Water Research 14(6):591-602.

The effects of industrial effluents and bacterial populations in the estuary near Humber, England, were studied. In general, growth of bacteria in the estuary corresponded to the amount of organic pollution in the water; no widespread inhibition of growth due to industrial wastes was found. At effluent discharge sites of a metal refinery, however, heavy metal concentrations affected bacterial growth adversely. (EL)

305. Goyal, S. M., and C. P. Gerba. 1979. Comparative Adsorption of Human Entero-viruses, Simian rotarirus, and Selected Bacteriophages to Soils. Applied Environmental Microbiology 38:

Virus adsorption to soils is considered to be the most important factor in removing viruses after land treatment of wastewater. Most of the studies on virus adsorption to soils have utilized poliovirus as the model system. In the present study, comparative adsorption of a number of different types and strains of human enteroviruses and bacteriophages to nine different soil types was studied. Under the experimental conditions of this study, greater than 90% of all viruses adsorbed to a sandy loam soil except echovirus types 1, 12, and 29 and a Simian rotavirus (SA-11), which adsorbed to a considerably lower degree. A great deal of variability was observed between adsorption of different strains of echovirus type 1, indicating that viral adsorption of soils is highly strain dependent. Of the five phages studied, f2 and ØX174 adsorbed the least. In addition to being dependent on type and strain of virus, adsorption was found to be influenced also by type of soil. Thus, soils having a saturated pH of less than 5 were generally good adsorbers. From these results, it appears that no one enterovirus or coliphage can be used as the sole model for determining the adsorptive behavior of viruses to soils and that no single soil can be used as the model for determining viral adsorptive capacity of all soil types. (AA)

306. Graetz, D. 1976. Dynamics of Sediments in the Cypress Domes. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

307. Graetz, D. A. 1980. Denitrification in Wetlands as a Means of Water Quality Improvement. Rept. No. 48. Univ. of Florida, Gainesville. 75 pp.

308. Graetz, D. A., P. A. Krottje, N. L. Erickson, J. G. A. Fiskell, and D. F. Rothwell. 1980. Denitrification in Wetlands as a Means of Water Quality Improvement. Publication 48. Water Resources Research Center, Univ. of Florida, Gainesville. 86 pp.

The feasibility of using natural wetlands to remove nitrogen via denitrification from secondarily treated municipal sewage effluent was studied. Nitrification and denitrification rates were measured in simulated marsh ecosystems, i.e., soil:water columns containing approximately 30 cm of marsh soil and either 15 or 30 cm of overlying water (secondarily treated sewage effluent). Nitrification was apparently rate limiting when nitrogen was supplied in the form of ammonium. Therefore, efficiency of nitrogen removal would be increased by allowing the nitrogen in wastewater to nitrify prior to entering the marsh. First-order denitrification was observed in soil:water columns. Average nitrate removal rates, assuming a floodwater nitrate concentration of 10 mg N liter^{-1}, were 1.2 kg N ha^{-1} without plants and 2.0 kg N ha^{-1}day^{-1} with plants.

Denitrification potentials of Florida wetland soils were determined using 15 soils with a wide range of texture, organic matter content, and soil reaction (pH). Denitrification followed apparent first-order kinetics, with rate constants varying from 0.040 day^{-1} to 0.192 day^{-1}. Nitrate removal rates, assuming a 10 mg N liter^{-1} floodwater nitrate concentration, ranged from 0.6 to 2.9 kg N ha^{-1}day^{-1}. Denitrification rate was significantly correlated with soil organic content and with soil pH. Nitrous oxide accounted for from less than 0.2 to 6.5% of nitrate consumed.

The experimental data obtained in this work indicate that many Florida wetlands could function as efficient treatment systems for nitrate-bearing wastewater and drainage water. Soils high in organic matter with a pH range of 5 to 7 would provide the most rapid removal rates. (AA)

309. Graetz, D.A, and J. Struble. 1975. Rates of Sedimentation: Sediments as a Nutrients Sink in Cypress Domes, pp. 561-563. In: H.T. Odum, K.C. Ewel, J.W. Ordway, and M.K. Johnston (eds.), Cypress Wetlands for Waste Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

310. Grant, R. R., Jr., and R. Patrick. 1970. Tinicum Marsh as a Water Purifier, pp. 105-123. In J. McCormick, R. R. Grant, and R. Patrick (eds.). Two Studies of Tinicum Marsh, Delaware and Philadelphia Counties, Pennsylvania. The Conservation Foundation, Washington, DC.

The general health of a marsh receiving water from a creek polluted by municipal sewage was studied in an attempt to assess the effectiveness of marshes in improving water quality. Results indicated that marsh vegetation and algae help reoxygenate water, reduce nitrates and phosphates, and generally enhance water quality.

311. Grasso, S. V. 1979. An Analysis of the Factors Affecting the Distribution of Heavy Metals in a Tidal Estuary. Ph.D. Diss. Rutgers Univ., New Brunswick, NJ. 288 pp.

312. Greenwald, C. M. 1981. Prediction of Songbird Responses to Habitat Alteration Resulting from Wastewater Irrigation. School of Forest Resources. Pennsylvania State Univ., University Park. 81 pp.

In an effort to predict songbird responses to habitat changes resulting from year-round spray irrigation of chlorinated municipal wastewater, relationships between habitat features and attributes of songbird populations and communities were studied on Penn State's Wastewater Renovation Facility. Habitat types in the study area ranged from shrubby old fields to mixed-oak forest. Songbirds were censused at 30 randomly chosen points four times between June 1979 and May 1980. Principal components analysis of the habitat measurements resulted in a reduction of the 34 original variables to nine habitat components. Multiple regression of avian community parameters in each season on the habitat components produced ten signficiant equations; fall and winter N could not be predicted.

313. Greer, D. E., and C. D. Ziebell. 1972. Biological Removal of Phosphates from Water. J. Water Pollut. Control Fed. 44:2342-2348.

Various organisms were tested for their ability to remove the orthophosphate ion from solution. A system incorporating natural algal successions and beds of the oriental clam Corbicula fluminea Muller was the most effective of the systems tested. Experiments were conducted under controlled conditions at concentrations of 5.0, 10.0, and 15.0 mg/l PO^3. Results indicated that this system can remove the PO^3 ion to below 0.10 mg/l in 16 days or less and yield a clear effluent. (AA)

314. Greeson, P.E., J.R. Clark, and J.E. Clark (eds.). 1979. Wetland Functions and Values: The State of Our Understanding, Proceedings of the National Symposium on Wetlands, Lake Buena Vista, Florida. Amer. Water Resour. Tech. Publ. TPS 79-2. Minneapolis, MN. 674 pp.

315. Greij, E. D. 1976. The Effects of a Marsh on Water Quality. Project Completion Report. Michigan Inst. of Water Res., Michigan State Uni. Lansing.

1073. Grimes, D. In press.

316. Gross, F., and G. Ryvarden. 1981. Effluent Treatment Systems Requiring No External Chemicals or Energy Supply for Use in Protected Groundwater Zones in the Chalk Uplands. Model Studies. Gas, Wasster, Warme, (Austria) 35(2):49-52.

Problems of sewage disposal in mountain refuges in protected areas used for groundwater supply are considered. Experiments are described in which a rudimentary biological filter was connected in series with a number of shallow containers forming a cascade system for aquaculture of phytoplankton and higher forms of plant life. The containers were arranged so that they experienced direct sunlight, and the system was fed with effluent from a septic tank. Progressive elimination of dissolved organic matter and ammonia occurred with a steady decrease of coliform counts through the action of the algae and the sedge grass in the basins; the possibility that antiobiotics are released by these grasses is considered to merit further study. By using a sufficient number of basins in series, effluent approaching the quality of raw water sources for potable supplies should be obtained. Methods of composting the sludge from the septic tank in a mixture with straw and quicklime were also tentatively investigated. (AL)

317. Guntenspergen, G., and F. Stearns. 1979. Ecology of an Ombrotrophic Bog in Northern Wisconsin. Bull. Eco. Soc. of Americal 60:135.

This study was designed to provide background information on plant nutrient content, primary productivity and biomass in an ombrotrophic bog. Such basic knowledge is lacking for ombrotrophic peatlands in North America. Our work concentrated on the herb and shurb layers and is part of a larger research effort investigating the biological and physiochemical nature of this community.

The study site is located in northeastern Wisconsin thirty miles south of Lake Superior in Bayfield County. The area is physiographically complex with calcareous maraines and wet depressions creating a diverse landscape. Drummond bog is a 22 acre perched bog system isolated from the influence of the regional ground water table. The mean pH is 4.5. Runoff from the upland is collected in the moat or lag zone around the bog.

318. Guntenspergen, G., W. Kappel, and F. Stearns. 1980. Response of a Bog to Application of Lagoon Sewage: The Drummond Project - An Operational Trial. Presented at the 6th International Peat Congress. Duluth, MN. Aug. 17-23. 8 pp. plus attachments.

The town of Drummond, in northwestern Wisconsin, completed a three-lagoon, secondary sewage treatment system in 1978. To avoid discharging the effluent into a Class 1-A trout stream, the U.S. Forest Service suggested a tertiary treatment alternative where the lagoon effluent passes through a 10 ha. bog.

Pretreatment data on water quality of the bog outflow, and productivity and nutrient content of the bog vegetation is typical for bogs of this type. Wastewater from the lagoons was applied to the bog during the 1979 growing season. Preliminary water quality analysis indicates that the bog is assimilating the nutrients in the effluent although the total loadings were relatively small. Plant tissue nutrient concentrations changed less than those in the surface horizons of the past.

Parameters other than nutrient immobilization require attention before the widespread use of such systems becomes common. The long term response of peatland ecosystems to sewage effluent disposal must be assessed. (AA)

319. Guntenspergen, G., and F. Stearns. 1981. Ecological Limitations on Wetland Use for Wastewater Treatment, pp. 273-284. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

Wetland use for tertiary treatment of sewage effluent is gaining widespread attention partly for economic reasons and partly because wetlands are presumed to absorb nutrients and retain them. At one time, surface waters were assumed to have an infinite capacity to absorb nutrients. The ecological consequences of that assumption were streams and lakes rich in phosphorus and nitrogen filled with blue green algae and nuisance plants; a condition called cultural eutrophication. Conventional sewage treatment is effective in removing organic material but not nutrients. Advanced wastewater treatment removes nutrients, but its cost is often prohibitive for small communities. These small communities need alternative techniques to treat their sewage and meet water quality standards.

What happens when nutrients are transferred from an effluent flow to a wetland? The ultimate result is still difficult to predict; we have an imprecise understanding of nutrient cycling at the ecosystem level. Traditionally the environment is viewed as an enormous sink and the usefulness of an ecosystem is measured by the amount of human waste it can absorb. Freshwater wetlands have long been thought to improve the quality of waters flowing through them. It was inevitable that these systems would be perceived as being capable of treating wastewater.

Two lines of inquiry are needed to evaluate this wetland alternative for waste disposal. First, we must determine the ability of wetland ecosystems to accommodate nutrient inputs, i.e., the effectiveness of the process. Second, we must examine the ecological consequences -- i.e., the wetland community response to large nutrient inputs.

1074. Guntenspergen, G.R. and F. Stearns. In press.

320. Gupta, G.C., 1980. Use of Water Hyacinths in Wastewater Treatment. Journal of Environmental Health. 43(2):80-82

A literature review is presented on the use of water hyacinths in sewage and wastewater treatment. Water hyacinths have been effective in removing algae, fecal coliforms, suspended particles, trace toxic metals, organics, and many other dissolved impurities from wastewater. Water hyacinths are classified as an aquatic pest, but culturing hyacinths in a sewage lagoon system can reduce BOD_5 up to 95%, total suspended solids up to 90%,, and also reduce nitrogen, phosphorus, heavy metals, and pesticides. Biological, chemical, and physical factors combine to remove contamination. Five and one-tenth acres of water hyacinths are needed for 1 mgd throughout to remove 80% of the nitrogen and 44% of the phosphorus. Hyacinths are effective and cheap where land is available and inexpensive.

321. Gupta, P.K. 1977. Dynamic Optimization Applied to Systems with Periodic Disturbances. Ph.D. Dissertation Univ. of Michigan, Ann Arbor.

322. Haag, R.D., Jr. 1979. The Hydrogeology of the Houghton Wetland. Ph.D. Dissertation University of Michigan, Ann Arbor.

323. Hagarty, E. P. 1978. Wastewater Disposal on Wetlands. North Carolina. Department of Natural Resources and Community Development, Division of Environmental Management. Raleigh, NC, 18 pp.

This report contains an overview of some of the wetland treatment system projects in the United States and the advantages, disadvantages, and uncertainties of such techniques as part of an analysis of the potential for the use of this type of treatment system in the coastal areas of North Carolina. The author recommends establishing a pilot study in North Carolina and identifies the general types of wetlands found there. (EPA)

324. Haines, E.B., 1974. Growth Dynamics of Cordgrass, *Spartina alterniflora* Loisel on Control and Sewage Sludge Fertilized Plots in a Georgia Salt Marsh. Estuaries 2(1):50-53.

Seasonal plant growth dynamics were followed for a year in undisturbed plots of tall and short form *Spartina alterniflora* and in plots of short form *S. alterniflora* which were enriched with sewage sludge. Monthly determinations of above ground live and dead biomass, density of live stems, the ratio of number of young shoots to total number of shoots, and below ground mass of macro-organic matter to a depth of 30 cm were made for each area. Sludge fertilization increased the live biomass of the short form *S. alterniflora* by up to 150% of the control live biomass, but had little effect on the dead biomass, stem density, or proportion of young shoots. There was a trend of increased amount of below ground macroorganic matter in fertilized compared to control plots during the last 6 months of the study. In all areas, there was a marked decrease in the proportion of young shoots from winter to early summer, followed by a rapid increase in the percent of young shoots from late summer to fall. Sampling of plots 7 and 20 months after termination of sludge enrichment showed higher plant biomass and % N content in surface soils, but no difference in N content or live plant tissue, in fertilized compared to unfertilized marsh. After 20 months, about half of the sludge nitrogen remaining in the soils of the fertilized plots had disappeared.

325. Haines, E. 1980. Salt Marsh Creation: Impact of Sewage. *In*: J.C. Lewis and E.W. Bruce (eds.), Rehabilitation and Creation of Selected Coastal Habitats: Proceedings of a workshop. (Rept. No. 80/27). Office of Biological Services. U.S. Fish and Wildlife Service.

A study of the capacity of a *Spartina* salt marsh to assimilate nitrogen from sewage was carried out in Georgia. Focus has been on the basic nitrogen cycle as well as the impact of applying sewage sludge to the marsh; specifically what happens to the nitrogen in the sludge.

Coastal urban areas have found disposing of raw sewage in coastal wetlands inexpensive and convenient. The increasing BOD has already resulted in deterioration of water quality in some northern estuaries. The processes in the estuaries tend to keep materials that come into estuaries within the estuary. Major components of sewage are plant nutrients, heavy metals, chemicals, pesticides, petroleum hydrocarbons, and pathogenic microorganisms. Evaluation of sewage impact is based on 1) accumulation of substances, 2) stimulation of biological processes, and 3) inhibition of microbial processes.

Salt marshes are not effective for secondary sewage treatment. However, estuaries may be efficient at tertiary treatment.

326. Hall, F., R. Rutherford, and G. Byers. 1972. The Influence of a New England Wetland on Water Quantity and Quality. Research Report No. 4. Water Resources Research Center. Univ. of New Hampshire, Durham, H.H.

327. Hallock, R.J., and C.D. Ziegell. 1970. Feasibility of a Sport Fishery in Tertiary Treated Wastewater. J. Water Pollut. Control Fed. 42:1656-1665.

The objective of this study was to test the feasibility of developing a sport fishery in tertiary treated domestic wastewater. Fish tested were channel cat fish, *Ictalurus punctatus*, rainbow trout, *Salmo gairdneri*, and Malacea *Tilapia* hybrids. Less than 1 percent survival occurred in five trout experiments and in one catfish experiment. An important cause of death was low oxygen sunrise tensions. This seemed to be a result of respiration by dense phytoplankton blooms, which were stimulated in part by high (14 mg/l) average inflow orthophosphate concentrations, and oxygen reduction through bacterial respiration. When fish survived, production was high. The highest combined yield of locally acceptable channel catfish and *Tilapia* from one pond was 697 lb/acre (779 kg/ha), a yield much greater than that from natural waters. *Chironomus* larvae, the predominant food organism, comprised 90 percent of the estimated annual benthic production of 12.680 lb/yr/acre (14,180 kg/yr/ha). Phytoplankton productivity averaged 10.2 g O_2/day/cu m. These tertiary treated waters, although highly productive, need more stable oxygen conditions to establish dependable fishery. (AA).

328. Hamdy, M. K. 1977. Biochemical Transformation and Detoxification of Mercury in Aquatic Environments. Rept. No. B-069-GA. Environmental Research Center. Georgia Institute of Technology. Atlanta. 85 pp.

329. Hammer, D. E., and R. H. Kadlec. [No date.] Wetland Utilization for Management of Community Wastewater - Concepts and Operations in Michigan. Industrial Development Division, Institute of Science and Technology, Univ. of Michigan, Ann Arbor. 28 pp.

This booklet contains a summary of the results of the operation of four wetland irrigation systems in Michigan (Bellaire, Houghton Lake, Kinross, and Vermontville). Basic concepts of the processes that use wetlands for advanced wastewater treatment are explained in easily understandable terms and diagrams. Implementation factors such as economics, site selection, design criteria, and monitoring procedures are discussed. (EPA)

330. Hammer, D. E., and R. H. Kadlec. 1980. Orthophosphate Adsorption on Peat Presented at the 6th International Peat Congress. Duluth, MN, Aug. 17-23, 1980. 19 pp.

331. Hammer, D.E., and R.H. Kadlec. 1982. (Preliminary Draft). Design Principles for Wetland Treatment Systems. Work conducted under cooperative agreement between U.S. EPA, Robert S. Kerr Laboratory, Office of Research and Development, Ada OK, and the University of Michigan, Ann Arbor, MI.

1075. Hammer, D.E. and R.H. Kadlec. 1983.

1076. Hammer, D.E. et al. 1983.

332. Handley, L. L. Effluent Irrigation of a Tropical Wetland Forage Grass in Hawaii. Presented at the Water Reuse Symposium II. Washington, DC. August 23-28, 1981.

California grass (*Brachiaria mutica* Forsk.) Stapf (*Panicum purpurascens* Raddi) irrigated with domestic sewage effluent shows excellent results as a means for water use, nitrogen removal and high productivity of medium grade fodder. This grass tolerates prolonged flooding and has a high transpiration rate. It has a broad geographic potential for use, as its range includes a large portion of the tropics and sub-tropics. In Hawaii it is used both as a pasturage for cattle and horses and for fodder for dairy cattle. The grass is allelopathic and forms a dense, easily maintained monoculture which is tolerant to Cl^- and Na^+.

California grass in eight percolate-style lysimeters was irrigated with sewage effluent, varying the volume and concentration of effluent. Irrigation water, soil percolate, and plant tissues were analyzed for nitrate/nitrite-nitrogen and ammonia plus organic nitrogen. Soil was analyzed for ammonia and mineralizable nitrogen. A water budget was kept and a mass balance for nitrogen and water was calculated.

At the highest irrigation levels (89 mm/week) percolate NO^-_3-nitrogen did not exceed 10 ppm, nor did nitrate-nitrogen accumulate to toxic levels in the grass.

Plant productivity was up to 156 mT/ha/year, dry weight. Irrigation of more than 76 mm/week decreased productivity slightly. Growth was also slightly depressed during lower winter temperatures.

Water use, as evapotranspiration, was about half of that of an adjacent Class A pan. Heavy irrigation and large water use are advantages in Hawaii where human population is dense and land is expensive and scarce. (AA)

333. Hanes, N. B., L. C. Brown, M. S. Bartlett, and N. H. Nickerson. 1979. Denitrification in Freshwater Wetland Soil. J. Env. Qual. 8(4): 460-464.

The application of secondary-treated wastewater to freshwater wetlands as a method of tertiary treatment has been studied. Nitrate removal in wetland soil-water suspensions was studied using a Warburg respirometer. All important pathways of nitrate reduction were accounted for using a nitrogen mass balance. Results show that 90 to 95% of the nitrate added to wetland soil-water suspensions is reduced to nitrogenous gasses, with little or no transfer of nitrate to ammonia nitrogen or organic nitrogen fractions. (AL)

334. Hansen, R. J., and J. W. DeWitt. 1967. A Study of Some Physical and Chemical Environmental Features of a Large Sewage Oxidation Pond. Part I. Final Report Humboldt State College, Arcata, CA. 133 pp.

The specific objective of this study was to gain background information concerning certain chemical and physical features of the Arcata, CA, sewage oxidation pond in order to assess waste treatment performance of the pond relative to future operational changes. Secondary objectives of the study were to evaluate present waste treatment performance of the Arcata pond and to determine its ability to support fish life. (NT)

335. Hanseter, R. 1975. Recovery, Productivity and Phosphorus Content of Selected Marsh Plants After Repeated Cuttings. Master's Thesis, Univ. Wisconsin, Oshkosh. 81 pp.

336. Hanson, R.B. 1977. Nitrogen Fixation (Acetylene Reduction) in a Salt Marsh Amended with Sewage Sludge and Organic Carbon and Nitrogen Compounds. Applied and Environmental Microbiology 33(4):846-852.

Results of a 12-month study on nitrogen fixation in a sewage sludge-amended Spartina alterniflora salt marsh were reported. Four 100-meter plots were used, two of these treated with sludge to the equivalent of 4 grams of nitrogen per square meter. The effects of nutrient amendment were also studied on similar plots, divided into 10 treatment areas. Half of these areas were clipped of S. alterniflora and enclosed in lawn edging to prevent lateral root movement. Clipped and unclipped plots were injected with glucose, ammonium nitrate, a combination of the two, rhodamine WD, and distilled water as a control. The acetylene reduction method was used to measure nitrogen fixation. No significant difference was found between the sludge-amended plots and the controls. Apparently sludge enhanced rhizosphere nitrogen fixation in the soil through stimulation of Spartina production. Other processes, however, such as denitrification, may be inhibited by sludge treatment. In the clipped and unclipped plots, nitrogen fixation was significantly lower in the clipped plots due to the lack of carbon input via the roots. Nitrogen fixation in the ammonium nitrate-enriched unclipped plot was increased, indicating that increased Spartina production from nitrogen addition out-weighed the inhibitory effect of inorganic nitrogen on nitrogen fixation. Glucose addition inhibited nitrogen fixation in the soil, perhaps due to its stimulation of microbial activity.

337. Hantzche, N.N. 1983. Wetland Systems for Wastewater Treatment: Engineering Applications (draft manuscript). *In*: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop 23-25 June 1982, University of Massachusetts, Amherst, MA. US Fish and Wildlife Service and US Environmental Protection Agency.

338. Harding, J.P.C., and B.A. Whitton. 1978. Zinc, Cadmium, and Lead in Water, Sediments, and Submerged Plants of the Derwent Reservoir, Northern England. Wat. Res. 12:307-316.

A partial budget is presented of the zinc, cadmium and lead entering the Derwent Reservoir. The mean levels in the water column upstream of the site of inflow are Zn. 0.216 mg/l; Cd. 0.003 mg/l; Pb. 0.065 mg/l; levels after passage through the 4.1 km^2 reservoir fall by: Zn. 70.3%; Cd. 98.3%; Pb. 89.2%. Most of these metals are deposited in sediments, the mean values for which are; Zn. 1035 micrograms/gram; Cd. 13 micrograms/gram; Pb. 827 micrograms/gram. Lead, a higher percentage of which occurs as particulate material, is deposited more rapidly than zinc; this effect is especially obvious when streaming of cold water along the bottom of the reservoir takes place at the time of floods. Macroscopic plants are only occasional in this reservoir, due perhaps in part to heavy metal toxicity. Of the two most common submerged species, *Nitella flexilis* probably accumulates almost all of its metal content directly from the water, but the data suggests that sediments are a source of some of the heavy metals accumulated by *Glyceria fluitans*. (AA).

339. Harlin, M.M., 1981. Nitrate Uptake by *Enteromorpha* spp. (Chlorophyceae): Applications to Aquaculture Systems. Aquaculture. 15(4):373-376.

Enteromorpha linza and *E. intestinalis* removed nitrates from a sea water test medium at rates considerably higher than those measured for other seaweeds. At 15 C these algae showed a V-max of 129 micro mol/h/g dry weight and a Ks of 17 micro M. At similar temperature and irradiance, Vmax and Ks for nitrates in *Enteromorpha* species are twice that of Codium fragile. In aquaculture systems where the objective is to strip nitrates from sea water, nitrate-rich water may be pulsed through tanks of *Enteromorpha* species during the day. Night feeding of *Chondrus crispus* culture tanks would capitalize upon the difference in nitrate uptake strategies between these two algae minimizing uptake by the *Enteromorpha*. This paper investigates three parameters that regulate nitrate uptake for *Enteromorpha linza* and *E. intestinalis*: temperature, lights, and substrate concentrations. At five C nitrate uptake was 19% of that measured at 15 C and at 0 C nitrate uptake was not detected. In darkness, nitrate uptake was reduced 35% in the first hour, 10% in the second hour. After standing in nitrate-depleted sea water, algae scavenged nitrate at concentrations 0.5 micro M and no nitrate leaked from the tissue into nitrate-free water. Nitrate uptake increased with increasing substrate concentrations.

340. Harmston, F.C., and L.J. Ogden. 1976. Mosquito Problems Associated with Man-made Impoundments in Western and Mid-western United States.

341. Harris, S.W., and W.H. Marshall. 1963. Ecology of Water-level Manipulations on a Northern Marsh. Ecology 44(2):331-343.

A study of vegetarian changes associated with marsh drawdowns at Agassiz National Wildlife Refuge, Minnesota, revealed that the development of five types of vegetation on mud flats during the first year was influenced by seed availability, soil type and moisture, season and duration of drawdown, and the amount of stranded algal debris. The more an area combined early season drawdown, rich soil types, slow rates of mud flat drainage, and small amounts of stranded algae, the greater was the development of emergent aquatics.

In the second year of drawdowns, most areas developed greater amounts of upland and shoreline weeds and fewer emergents. Areas originally exposed before August of the first year lost emergent cover during the second year, while the reverse was true of areas exposed later in the first year. Specific changes were influenced by density and comosition of residual vegetation, soil types, and soil moisture. During longer drawdowns the soil dried more completely, and over a 5-year period nearly solid stands of willow developed.

Upon reflooding, mud flat and shoreline annuals were eliminated and marshes of cattails, soft-stem bulrush, sedges, spike-rush, willows, and aquatic annuals developed in the first year. Specific development in subsequent years was determined by the nature of the residual vegetarian and the depth of the restored water. (AA).

342. Harter, R.D. 1966. The Effect of Water Levels on Soil Chemistry and Plant Growth of the Magee Marsh Wildlife Area. Ohio Game Mono. No. 2. Ohio Div. of Wildlife, Columbus. 36 pp.

343. Hartland-Rowe, R. C. B., and P. B. Wright. 1974a. Effects of Sewage Effluent on a Swampland Stream, pp. 1575-1584. In V. Sladecek (ed.), Proceedings of the International Association of Theoretical and Applied Limnology (Verh. Int. Ver. Limnol).

Wastewater was introduced into a riverine wetland near Hay River, Northwest Territories, Canada. A variety of water quality parameters were studied. Dramatic improvements were shown observed for many parameters, including total phosphorus and suspended solids. (EP)

344. Hartland-Rowe, R. C. B., and P. B. Wright. 1974b. Swamplands for Sewage Effluents. Final Report. Prepared for the Environmental-Social Program, Northern Pipelines, of the Task Force on Northern Oil Development. Information Canada. Ottawa, Ontario, Canada, 137 pp.

This is the final report of the two-year study described in Hartland-Rowe and Wright (1974a). The creek flows intermittently into Great Slave Lake and broadens in a number of locations into pools bordered with Carex. Some standing crop measurements and phosphate analyses of sediment cores and root masses were made in addition to the primary research on water quality. (EP)

345. Harvey, R. M., and J. L. Fox. 1973. Nutrient Removal Using *Lemna minor*. J. Water Pollut. Control Fed. 45(9):1927-1938.

Wastewater nutrient removal capabilities and economic resource potential of *Lemna minor* are investigated and discussed. *L. minor* was selected over *Woffia Columbiana* and *Salvinia rotundiflora* as the priincipal subject of the investigation because it was the only one of the three species screened that was both easy to harvest and has a high forage potential. *Lemna* removed substantial quantities of nitrogen and phosphorus from secondary effluent under batch laboratory conditions. Dried *Lemna* plants contained 4.59% nitrogen and 0.80% phosphorus. *Lemna* was found to double its area every 4 days and is as good or better than common pasture grass as a cattle feed based on digestability testing. Furthermore, harvesting costs are low because of its small size and free floating nature. (AA)

346. Haughey, A. W. V. 1968. The Planktonic Algae of Auckland Sewage Treatment Ponds. New Zealand J. of Marine and Fresh Water Resources 2: 721-766.

347. Haughey, A. W. V. 1969. Further Planktonic Algae of Auckland Sewage Treatment Ponds. New Zealand J. of Marine and Freshwater Resources 3:245-261.

348. Haung, C. P., H. A. Elliott, and R. Ashmead. 1977. Interfacial Reactions and the Fate of Heavy Metals in Soil-water System. J. Water Pollut. Control Fed. 49:745-756.

The fate of heavy metals in soil-water systems is primarily controlled by the congruent-incongruent solubility of the carbonates, oxides, sulfates, and sulfides of metals and by the adsorptions of free and complexed metals at solids-solution interface. The presence of organic substances modifies the overall interfacial reactions. Adsorption of copper, zinc, lead, and cadmium increased abruptly at a give pH when the free metal ionic species dominates the system. At low pH, lead and cadmium were negatively adsorbed, which results in an excess of lead and cadmium ions in the bulk solution phase. Copper and zinc were always adsorbed by all four solids (SiO_2, AL_2O_3, Evesboro, and Metapeak) investigated. In a neutral to acidic environment, the adsorption reaction appears to be the most important process in controlling the chemical makeup of the soil water system. (AA)

349. Have, M. R. 1973. Effects of Migratory Waterfowl on Water Quality at the Montezuma National Wildlife Refuge, Senec County, New York. J. Research 1(6).

Studies were conducted in response to shellfish industry's concern that bacteria effluent from northeastern wildlife refuges were adversely affecting shellfish. Results showed that the net effect of the refuge is to improve the quality of the water which flows through it.

350. Heimburg, K.F. 1976a. Hydrology of Some North-Central Florida Cypress Domes. Master's Thesis, Department of Environmental Engineering Sciences, University of Florida, Gainesville. 115 pp.

351. Heimburg, K.F. 1976b. Hydrology and Water Budgets of Cypress Domes, pp. 56-67. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnson (eds.), Cypress Wetlands for Water Management, Recycling and Conservation. Third Annual Report. Center for Wetlands, Univ. of Florida, Gainesville.

Intensive hydrological measurements in two cypress domes near Gainesville, FL, were conducted between 30 May 1975 and 30 April 1976. This report is a summation of findings detailed in Heimburg (1976a).

352. Heimburg, K. 1977. Use of Florida Cypress Domes as Tertiary Treatment Facilities, pp. 165-177. In C. B. DeWitt and E. Soloway (eds.), Wetlands Ecology, Values, and Impacts. Proceedings of the Waubesa Conference on Wetlands held at Madison, Wisconsin, 2-5 June 1977. Institute for Environmental Studies, Univ. of Wisconsin, Madison.

Cypress domes can function as tertiary treatment facilities. Long range questions about the accumulation of nutrients in the sediments and the importance of any virus that may escape to the water table aquifer do remain, however.

Because the wastewater load is limited by wet seasons to something under an inch per week it seems that this treatment alternative would be most attractive in small scale applications, such as the trailer park that produces the effluent used in the experiment. In addition, small developments like this are least likely to be able to afford tertiary treatment. Ordway (1976) has made cost estimates for this disposal technique that show it to be competitive, even considering land and piping costs, factors not usually considered in treatment cost estimates. Boyle Engineering, Inc., of Orlando is currently involved in a study comparing the cypress dome treatment method with others with which they have extensive experience.

Although the final word will not be in for some time, tertiary treatment via cypress swamps does look like a technically and economically feasible way to meet 1983 water quality standards while helping to recharge deeper aquifers. (AA).

353. Heimbuch, D. G., S. Perretta, and J. G. Nickum. 1978. Cultured Daphnids as a Biological Wastewater Treatment System for Oxidation Pond Effluent Clarification. Tech. Completion Rept. Office of Water Research and Technology, Washington, D.C. 68 pp.

The technical feasibility of culturing Daphnia magna in flowing water and their function as biological filters for removing algae from the effluent of simulated oxidation ponds was demonstrated. Greatest daily increases in daphnid population biomass in 5.5 liter culture vessels were observed in populations receiving flows of low algal concentration (3 mg/l) and high flow rate (240 ml/min). The maximum four day average increase for three replicate populations of that treatment was 136 mg (dry weight)/liter/day. Water leaving the culturing vessels of the 3 mg/l x 240 ml/min treatment had significantly lower concentrations of total nitrogen, total phosphorus, and volatile suspended solids than water entering the vessels; however, control vessels with no daphnid populations achieved similar reductions in total nitrogen and total phosphorus. Concentrations of volatile suspended solids were reduced significantly in vessels containing daphnids in comparison to control vessels. Concentrations of ammonia nitrogen and ortho-phosphate increased significantly in passing through culture vessels containing daphnid populations. (NT)

354. Heinz, G. 1979. Methylmercury: Reproductive and Behavioral Effects on Three Generations of Mallard Ducks. Journal of Wildlife Management 43:394-401.

355. Hejkal, T.W. 1978. The Importance of Viruses Associated with Solids in Water. Ph.D. Thesis Florida State University.

1077. Heliotis, F.D. 1981.

356. Heliotis, F.D. 1982. Wetland Systems for Wastewater Treatment: Operating Mechanisms and Implications for Design. Instructional Program, Institute for Environmental Studies; University of Wisconsin-Madison. IES Report No. 117. 68 pp.

1078. Heliotis, F.D. and C.B. Dewitt. 1983.

357. Helz, G. R., J. M. Hill, and R. J. Huggett. 1975. Behavior of Mn, Fe, Cu, Zn, Cd, and Pb Discharged From a Wastewater Treatment Plant into an Estuarine Environment. Water Research 9(7):631-636.

Studies have been carried out on the Back River, MD, a small estuary tributary to the Chesapeake Bay which receives effluent from the principal sewage works of Baltimore, to obtain information on the fate of trace metals discharged to the estuarine environment. Except possibly for Mn and Fe, the decrease in metal concentration within 2-3 km of the outfall is much greater than can be ascribed to simple dilution, and the metals must be removed to the sediments. However, after the initial decrease, concentrations of Mn and Cd in the water begin to increase again, suggesting remobilization from the sediment. Of the metals studied, Cd poses the greatest risk because its input from sewage probably exceeds fluvial input, it appears to be readily remobilized from sediments, and it is known to be toxic to many organisms. (AL)

358. Hemond, H., and W. Nuttle. 1983. Significance of Hydrology to Wetland Nutrient Processing (draft document). In: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop, 23-25 June 1982, University of Massachusetts, Amherst MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

359. Henderson, C., Q. H. Pickering, and J. M. Cohen. 1959. The Toxicity of Synthetic Detergents and Soaps to Fish. Sewage and Industrial Wastes 31:295-306.

360. Henderson, S. 1977. An Evaluation of Filter-feeding Fishes for Water Quality Improvement. Arkansas Game and Fish Comm., Little Rock, AR

361. Henderson, S. 1979. Utilization of Silver and Bighead Carp for Water Quality Improvement, pp. 309-317. In R. K. Bastian and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. U.S. Enviromental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC. EPA 430/9-80-006.

Filter feeding fishes, the silver carp, Hypopthalmichthyes molitrix and bighead carp, Aristichthyes mobilis, were stocked in an existing lagoon treatment system in 1975-76 for a preliminary evaluation of the effect of the fish on water quality and the potential of this nutrient source for fish production. Positive results have led to an ongoing Environmental Protection Agency funded study of the efficacy of finfish as a treatment method in a full scale, six cell (24 acre) treatment facility at Benton, Arkansas.

Information concerning water quality improvement, fish production, product utilization and some design considerations are presented. The promising results, design adaptability, and pay back possibilities make this an attractive, innovative alternative. (AA).

362. Henderson, U. B., and F. S. Wert. 1978. Feed Fish Effluent and Reel in Savings. Water and Wastes Engineering 15(6):38-39 and 43-44.

The cost-effectiveness of aquaculture is compared with that of more conventional sewage-treatment methods. Fifteen technically feasible strategies appropriate for an influent flow of 200,000 gal per day, and consisting of various combinations of activates-sludge process, biological filters, and waste-stabilization lagoons with aquaculture raceways and aquaculture fish lagoons were selected for comparison. The results are tabulated and indicate that aquaculture wastewater treatments are viable systems, though further scientific documentation of removal efficiencies is needed. (AL)

363. Henderson, U. B., and F. S. Wert. 1976. Economic Assessment of Wastewater Aquaculture Treatment Systems. U.S. Environmental Protection Agency, Office of Research and Development. EPA 600/2-76-293. 120 pp.

This study attempted to ascertain the economic viability of aquaculture as an alternative to conventional wastewater treatment systems for small municipalities in the Southwestern region of the United States. A multiple water quality objective level cost-effectiveness model was employed. A total of fifteen wastewater treatment strategies, eleven with aquaculture systems and four without aquaculture, were examined. Estimates were made of the technical effectiveness and the present value of costs for all strategies. Estimates of the current value of revenues derived from sale of products produced in the aquaculture systems were made, and the impact of such revenues on total costs was analyzed. In all cases, when aquaculture was deemed capable of achieving a given water quality objective, the aquaculture system compared to a conventional system was cost-effective. The cost differentials between aquaculture and conventional strategies were highly significant ranging from a low 3.8% to a high of 94%. While certain data limitations exist, especially in the area of water quality estimates, aquaculture systems appear to be low cost alternatives to conventional wastewater treatment systems. (AA)

364. Hendricks, D. W., W. D. Pote, and J. G. Andrew. 1970. A Thermodynamic Analysis of a Primary Waste Stabilization Pond. Utah Water Research Lab. Logan, UT. 72 pp.

A 97.5 acre oxidation pond with an average depth of 1 1/2 to 1 2/3 meters, in operation since 1967, was sampled in September 1969 and in June 1970. The primary objective was to quantitate the actual energy trade-off, in terms of algae produced vs. amount of waste degraded, for oxidation ponds. The results defined respectively: the calculated absolute lower limit of daily algal synthesis necessary for production of the stoichiometric oxygen to satisfy the daily influent BOD requirement; measured daily synthesis rate of algae to compare with the daily influent TOC, under conditions of maximum sunshine in the annual cycle; and the calculated absolute upper limit of daily algal synthesis, through the annual cycle, if all usable solar energy were utilized. (NT)

365. Henley, D.A. 1978. An Investigation of Proposed Effluent Discharge into a Tropical Mangrove Estuary. pp. 43-64. In: Water Pollution Control in Developing Counties. Proceedings of the International Conference, Bangkok, Thailand. February, 1978.

Described are environmental studies carried out to determine the likely effects of effluent discharge into a mangrove-fringed estuary at Darwin in northern Australia. The oceanographic studies are described together with the statistical method used to calculate likely buildup of pollutants within the estuary. Studies of the nutrient status of the mangrove, including their sediments, are also described. They were used to assist in determining likely effects on the mangroves of an increase in nutrient. It was concluded that effluent from a primary-secondary lagoon system could safely be discharged within the mangrove areas with no detrimental effect.

366. Hermann, A.J. 1980. Nitrogen Cycling in a Freshwater Marsh Receiving Secondary Sewage Effluent. Master's Thesis. Department of Environmental Engineering Sciences. Univ. of Florida, Gainesville. 301 pp.

367. Hermann, A., J. Zoltek, S. E. Bayley, and T. Dolan. 1979. Nutrient Budget in a Fluctuating Freshwater Marsh System in Florida. In J. C. Sutherland and R. H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI.

The effect of secondarily treated municipal sewage effluent on the nitrogen and phosphorus budgets of a central Flordia freshwater marsh was evaluated. Four 2000 m^2 experimental plots were constructed in the marsh. Three of the plots received effluent at controlled rates of 1.3, 3.8, and 10.2 cm/wk, respectively. A fourth control plot received municipal freshwater at a controlled rate of 3.8 cm/wk.

Effluent and freshwater were applied to the respective plots over a 24-hour period once each week. Fiberglass walls were placed around the perimeter of each plot to a depth of 0.5 m in the peat substrate to retain applied water. Screened wells were installed to the bottom (1.5 m) of the peat substrate in the northwest corner of each plot for water quality sampling.

Effluent and all well samples were analyzed for nitrate nitrogen, nittrate nitrogen, ammonium nitrogen, total Kjehldahl nitrogen, orthophosphorus, and total phosphorus. Aboveground vegetation, root, and peat samples were analyzed for total nitrogen and total phosphorus content.

368. Hess, A.D., F.C. Harmston, and R.O. Hayes. 1970. Mosquito and Arbivorus Disease Problems of Irrigated Areas in North America, pp. 443-459. In: Critical Reviews in Environmental Controls (November).

369. Hickey, L.S. and P.C. Reist. 1975a. Health Significance of Airborne Microorganisms From Wastewater Treatment Processes. Part I. Summary of Investigations. J. Water Pollut. Cont. Fed. 47(12):2741-2757, 1975.

Published field measurements and related investigations of viable bacterial aerosols generated from wastewater are summarized in detail. Bacterial aerosols of up to 1,170 viable particles/cu ft (41,785.71/cu m) of ambient air have been recovered near aerated wastewater sources. These aerosols persist in much lower concentrations [about 5 viable particles/ cu ft (178.57 cu m)] several hundred yards downwind. Interference from other aerosol sources generally is not controlled in samples taken at great downwind distances from the presumed source. Pathogenic genera and species of bacteria are identified frequently from recovered particles in the human respirable size range. Limited data indicate virulence retention by some organisms. Investigators generally infer a respiratory disease hazard from experimental results. Viable aerosols from land application of wastewater have not been examined adequately in the field. However, health hazards attributed to aerosols from this source have also been postulated. Aerated wastewater also generates protein-bearing particulate aerosols with suggested allergenic significance. No evidence of health effects in exposed groups attributable to viable aerosols has been reported, the single applicable health survey being inconclusive.

370. Hickey, L.S. and P.C. Reist. 1975b. Health Significance of Airborne Microorganisms From Wastewater Treatment Processes. Part II. Health Significance and Alternatives for Actin. J. Water Pollut. Control Fed. 47(12):2758-2773, 1975.

The air transport route for viable bacterial aerosols from aerated wastewater to residential areas has been demonstrated by field studies. Land application of wastewater by spraying is postulated to have a much higher potential for production of viable aerosols than conventional aeration. Various field sampling protocols yield similar results, but samplers capable of providing particle size characteristics and volumetric concentrations of viable aerosols are preferred in field studies. Viable particles recovered range in diameter from 2 to 10 microns and are predominantly in the human respirable size range. Wind speed and die-off from evaporative stress influence viable aerosol dispersion and survival. Selective aerosolization and survival of particular bacterial species reflect the need to develop a valid index agent for monitoring viable aerosols. Some evidence supports the existence of a health hazard from viable wastewater aerosols. However, lack of evidence of actual disease transmission by these aerosols divides professional opinion on the question. Examination of susceptible exposed groups is indicated. (AA).

371. Hickok, E.A. 1979. Wetlands and Organic Soils for the Control of Urban Stormwater. In: Lake Restoration, EPA Report No. 440/5-79-001.

A seven-acre wetland in the Minnehaha Creek Watershed District, Minnesota, was studied during 1974 through 1975 to determine its effect on stormwater runs. Influent and effluent water sources and amounts were monitored to develop water and nutrient balances. Instrumentation used includes 5 parshall flumes, 13 polyvinyl chloride observation wells, and a complete weather observation station. Physical entrapment, microbial utilization, plant uptake, and adsorption were all found to be active mechanisms in the wetland system. The phosphorus adsorptive capacity of the area indicated that the organic soils of the watershed contain between 5 and 17 times the amount of phosphorus expected. Application of study results led to the development of five projects: (1) extensive environmental planning and construction was done for the building of a new shopping center in the study area; (2) a biologically activated soil filtration unit was constructed to filter phosphorus from the hypolimnion water of Wirth Lake in Minneapolis; (3) an oil retention basin, a six-acre wetland treatment area, and a filter dyke for drawdown were developed for a watershed at the Minneapolis St. Paul airport; (4) a marsh is being utilized by Annandale, Minnesota, to treat combined urban runoff and treated wastewater; and (5) organic soils and wetlands are being used for the Long Lake Restoration Project.

372. Hickok, E.A., Hannaman, M.C. and N.C. Wenck, 1977. Urban Runoff Treatment Methods. Vol. I. Non-Structural Wetland Treatment. Hickok (Eugene A.) and Associates, Wayzata, MN. NTIS No. PB-278 172. EPA Rpt. No. 600/2-77-217. 131 p.

The detrimental effects of stormwater runoff in the Minnehaha Creek Watershed District in Minnesota, leading to reduced water quality in Lake Minnetonka, may be alleviated by utilization to adjacent wetlands. The non-structural use of wetlands for the retention of phosphorus and suspended solids from urban runoff has been demonstrated as a feasible means of controlling runoff and water quality; the renovation of the stormwater runoff in the wetland occurred by a combination of physical entrapment, microbial transformation, and biological utilization. The wetlands studied has a phosphorus retention capacity about 5.5 times that of soil and retained 77% of all phosphorus and 94% of the total suspended solids entering the site. The physical entrapment of contaminants was attributed to the fine texture of the wetland soil, which is also responsible for reducing the velocity of the groundwater movement. The non-structural use of the wetland for controlling urban runoff had no apparent impacts on the wildlife or vegetation in the area.

373. Higman, D., 1973. Emergent Vascular Plants of Chesapeake Bay Wetlands pp. C72-C80. In: Army Corps of Engineers, Chesapeake Bay Existing Conditions Report. Appendix C., Vol. 2

Two annotated checklists have recently been compiled for vascular plants of the Chesapeake Bay and areas potentially subject to flooding by it (Krauus et al. 1971; Wass. 1972). The Maryland list of 421 species covers all land areas within the high tide limits of the Bay and its tributaries both in Maryland and Virginia. The Virginia Institute of Marine Sciences (VIMS) list of 435 species is restricted to Virginia (including the Barrier Islands of the Atlantic seashore) and the Patuxent River estuary in Maryland. Both lists include the flora of salt and brackish marshes, beaches, and freshwater swamps. The VIMS also covers ponds and floodplains on tidal creeks and shores subject to storm wave inundation. Each list contains many species not found in the other, so together they probably comprise a fairly complete flora of Chesapeake Bay wetlands. Since the distribution of many salt marsh species depends to some degree upon salinity, engineering projects which alter the salinity of portions of the Bay likewise alter the floristic composition of salt marshes in the affected areas. Pollution by sewage raises the level of nutrients in salt marshes. Wass and Wright (1969) noted that Spartina spp. grows taller and has a darker green color than normal when sewage is present. During the growing season, salt marshes are able to absorb some of the excess nutrients which otherwise would create algal blooms in the estuaries.

374. Hillman, W.S., and D.D. Culley, Jr. 1978. The Uses of Duckweed. Amer. Scientist 66:442-451.

Duckweed is capable of removing organic and inorganic materials from wastewater. It is particularly effective for reducing nitrogen and phosphorus concentrations and less effective with toxic chemicals or heavy metals. Duckweed will tolerate micronutrients such as Cu, Zn, and B. It will grow in the presence of high concentrations of sodium and will survive in high concentrations of potassium, phenols, or other organic substances.

The principles and observations we have presented are not new in any fundamental sense, though they may be unfamiliar in combination. The central concept is that of using a new crop, or group of crops, not primarily in monoculture but in polyculture systems having several integrated functions. Because it is a concept not fully at ease with more traditional views of agriculture, aquaculture, or waste management, a good deal more research and development is needed to apply it successfully. While the Lemnaceae, specifically, are by no means the only plants with promise for systems such as the dairy farm model described, their unique growth characteristics and worldwide distribution offer important advantages. Current concern with problems of the environment and limited resources should direct attention to this and other novel approaches to managing them. (AA)

375. Hinde Engineering Co. 1979. Little Fish, Big Help in Sewage Treatment, Farm Pond Harvest 13(1):8.

For the first time, Muskelunge, an American game fish, were raised in a sewage treatment lagoon. The village of Dorchester, WI donated its lagoons for the project that was supervised by the Wisconsin Department of Natural Resources. Raising the fingerling muskies in the lagoon produced both high quality fish and high quality effluent from the lagoon. Minnows feed directly on natural foods in the treatment lagoons and muskies feed on the minnows. A substantial portion of the phosphates were removed; 5.5 mg/l in the influent to 2.4 mg/l in the effluent after treatment in the fish lagoons.

376. Hodson, R. E. 1980. Microbial Degradation of Industrial Wastes Applied to Freshwater Swamps and Marshes. Rept. No. A-082-GA. Georgia Institute of Technology. Atlanta.

Methodology has been developed for assessment of the effects of organic industrial wastes on the natural geochemical activities of aquatic microbial populations in marshes and swamps in the coastal plain of Georgia. Wetlands are receiving increasing pollutional burdens due to the rapid industrialization of this region. Several schemes have been proposed for the utilization of wetland environments as natural "tertiary treatment facilities" to detoxify the industrial effluents prior to their introduction into larger streams and estuarine ecosystems.

1079. Hodson, E. et al. In press.

377. Hoeppel, R. E. 1974. Nitrogen Transformations in Wetland Soils. Misc. Paper Y-74-4. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS. 21 pp.

Nitrogen transformation pathways are often complex in soils that are periodically subjected to submergence. Both biochemical and chemical mechanisms can be implicated in these transformations. Nitrate accumulation in the environment has caused much conern recently due to its build-up in animals that lack the ability to reduce it. Young infants and many ruminant animals lack nitrate-reducing enzymes, and eventually this may lead to respiration difficulties. However, nitrate, or intermediates leading to its formation, must first be present in order to remove considerable excesses of combined nitrogen from the soil. The report discusses these processes in wetlands. (NT)

378. Holley, E. R., Jr., and D. R. F. Harleman. 1965. Dispersion of Pollutants in Estuary Type Flows. Report No. 74, T65-02. Massachusetts Inst. of Technology. Cambridge, MA. 202 pp.

A review is given of the procedures which have been used for modeling dispersion in estuaries. The results of this investigation may be used to estimate the time averaged dispersion coefficient in the equation for constant density portions of tidal estuaries. (NT)

379. Hook, J.E. and T.M. Burton. 1979. Nitrate Leaching From Sewage-irri-Perennials as Affected by Cutting Management. J. Environ. Qual. 8:496-502.

380. Hopkins, H.P., Jr. 1981. In-situ Evaluation of the Filtering Function of a Piedmont Creek Swamp During High and Low Flows. Rept. No. A-071-GA. Georgia Institute of Technology. Atlanta.

381. Horsefield, D.R. 1968. Master Wastewater Collection and Treatment Plan for Bogota, Columbia. J. Water Pollut. Control Fed. 40:1443-1458.

382. Hortenstine, C.C. 1976. Chemical Changes in the Soil Solution From a Spodosol Irrigated with Secondary Treated Sewage Effluent. J. Environ. Qual. 5:335-338.

383. Howard-Williams, C., and W. Howard-Williams. 1978. Nutrient Leaching from the Swamp Vegetation of Lake Chilwa a Shallow African Lake. Aquatic Botany 4(3):257-268.

The decomposition of Typha domingensis Pers. was investigated in Lake Chilwa, a shallow endorheic tropical lake. The decomposition curve showed a typical rapid initial weight loss, followed by a slowing down of this process. The amounts of various elements released by the physical leaching process during the 1st rapid weight loss period were investigated experimentally. A significant proportion of the ions were released from the dead Typha shoots on the 1st day of contact with water. During this short period, loss by leaching amounted to: Na, 26%; K, 7.5%; Ca, 9.2%; Mg, 11.5%; P, 1.5%; and N, 0.3%. The significance of this rapid leaching process is discussed in relation to the field conditions prevailing in the Lake Chilwa swamps, and to the general applicability of using swamps to remove nutrients from polluted waters. (BA)

384. Hruder, S.E., 1981. Water Reclamation and Reuse. J. Water Pollut. Control Fed. (Literature Review Issue), 53(6):751-767.

A literature review is presented of publications on water reclamation and reuse published during 1980. Several reviews of current and recent water reclamation and reuse practices in the U.S., Japan, the Netherlands, and South Africa became available. Papers on water reuse planning and allocation considerations included an evaluation of a series of computer models for water reuse planning. On the topic of agriculture and irrigation, several NTIS bibliographies were published, and studies dealt with such topics as salinity problems associated with municipal and industrial effluent reuse. Several publications reported investigations of the long-term effects of land irrigation with municipal wastewater. Aquaculture and wetland systems received attention in publications including an engineering assessment of aquaculture wastewater systems. Water reuse for groundwater recharge was the topic of a California symposium and other papers. The reuse of industrial water was explored for the pulp and paper industry, the textile industry, and organic chemicals processing; petroleum, coal, and synthetic fuels processing; inorganic chemicals processing, steel mills, metal processing and finishing, recirculating cooling systems and power generation, and other miscellaneous processes. Domestic reuse remained controversial, and health aspects of reclamation and reuse were considered in papers dealing primarily with bacteria and viral pathogens.

385. Huggins, T. G. 1969. Production of Channel Catfish (Ictalurus punctatus) in Tertiary Treatment Ponds. Master's Thesis. Iowa State Univ., Ames. 120 pp.

386. Huggins, T.G. 1970. Fish Production in Tertiary Ponds. Southwest Water Works Journal 51(12):20-22.

387. Huguenin, J. E., and J. T. Kildow. 1974. Social, Political, Regulatory, and Marketing Problems in Marine Saste-food Recycling Systems,

pp. 344-357. In Wastewater Use in the Production of Food and Fiber. U. S. Environmental Protection Agency. Ada, OK.

388. Huguenin, J. E., and J. H. Ryther. 1974. Experiences with a Marine Aquaculture Tertiary Sewage Treatment Complex, pp. 377-386. In Wastewater Use in the Production of Food and Fiber-Proceedings. EPA-660/2-74-041 Environmental Technology Series. Washington, D.C.

Treated secondary sewage effluent has been shown to be a good complete fertilizer for the growth of microscopic marine plants (phytoplankton), which form the base of the marine food chain. From this fact emerged the concept for a combined aquaculture-tertiary sewage treatment system. While the optimal operating points for the two objectives of nutrient removal and maximizing aquacultural output are not coincident, they are close enough to make a combined system feasible. The paper outlines briefly and discusses design problems and features of such a system. The essence of the concept is a treated sewage-marine phytoplankton-bivalve mollusk food chain. Data and experience notes from the Woods Hole Oceanographic Institution, where such a system is presently in operation, are included in the report. (NT)

389. Hunt, P.G. and C.R. Lee. 1976. Land Treatment of Wastewater by Overland Flow for Improved Water Quality, pp. 151- . In: J. Tourbier and R.W. Pierson, Jr. (eds.), Biological Control of Water Pollution. Univ. of Pennsylvania Press, Philadelphia.

This paper presents an overview of land treatment of wastewater, a somewhat detailed development of the overland flow system of treatment, which is probably the least understood mode of land treatment of wastewater; and possible modifications of current concepts of overland flow treatment for improved water quality.

390. Hunter, J. V., and T. A. Kotalik. 1973. Chemical and Biological Quality of Treated Sewage Effluents, pp. 6-25. In W. E. Sopper and L. T. Kardos (eds.), Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland. Pennsyvlania State Univ. Press, University Park, PA.

391. Hurtubise, F.G., 1974. Problems of the Canadian North. pp. 75-84. In: International Symposium on Wastewater Treatment in Cold Climates. Environment Canada Economic and Technical Review Report. EPA 3-WP-74-3.

The role of the Canadian Environmental Protection Service is examined. Projects in the Northwest Territories are outlined. These include: a study on the use of swampland lakes for sewage treatment; the use of vacuum and recirculating toilet units for sewage collection with subsequent incineration disposal; feasibility of land disposal of sewage effluent or use as fertilizer in permafrost areas; the practicability of the use of physical-chemical and rotating bio-disc treatment plants; the use of lagoon systems to serve isolated institutions; and the use of plasticized paperbags to replace garbage cans.

____. Hyde, H.C. et al. In press.

392. Hynes, H.B.N., 1969. The Enrichment of Streams. pp. 188-196. In: Eutrophication: Causes, Consequences, and Corrections. Printing and Publishing Office, National Academy of Sciences, Washington, D.C.

The term eutrophic, with its connotations of aging and evolution, cannot be properly applied to running water. Streams change along their length, increasing in discharge, width, depth, temperature, and transport of suspended matter and dissolved solids. Running water tends to be more fertile than standing water, but primary production is patchy due to turbulence and washout conditions. Community respiration is greater than photosynthesis is all but the most highly enriched streams. Input of sewage effluent enriches streams by increasing allochthonous organic matter near the effluent source and by increasing the concentrations of nutrient salts farther downstream. Additional nutrient inputs occur through leaching of agricultural soils (Wisconsin Data--12 lb. nitrate nitrogen and 0.6 lb. phosphate/square mile per day). Land clearing, channelization and swamp drainage have converted streams into better producers. Stream floras tend to be opportunistic species (Myriophyllum, Potamogeton, Cladophora, Oscillatoria) which will invade newly-enriched substrates. Production of large rivers is dominated by planktonic diatoms and rotifers: turbidity appears to be major limiting factor. High temperatures, low discharges and low turbidities as found in impoundments are favorable for the development of chlorophycean and myxophycean flora and resultant increase of primary production.

393. Incropera, F. P., and J. F. Thomas. 1977. A Model for Oxygen and Biomass Production in a Mass Algal Culture. Office of Water Research and Technology. Purdue University, Lafayette, IN. Washington, DC. 87 pp.

The primary purpose was to develop a reliable model for predicting the yield of a mass culture of unicellular algae in wastewater treatment ponds. Such algal cultures are capable of producing a high protein food supplement. The model developed determines both oxygen and algal biomass production and is based upon the use of available insolation data. It accounts for spectral effects in the photosynthetically active region, as well as directional effects through delineation of the diffuse and collimated components of the radiation. The effects of the air-water interface are treated, and predictions of the radiation field within the water are used with a representative photosynthesis model to predict the hourly yield. Calculations have been performed for the Indianapolis, IN, region, and comparisons with field data for similar latitudes reveal that the model is well suited for predicting the maximum yield of mass cultures. (NT)

394. Institute of Water Pollution Control. 1977. Environmental Pollution and Agriculture. Water Pollution Control 76(4):505-510.

Examples of pollution caused by agricultural activities and of the effects of pollution on agriculture are presented; water-quality criteria for spray irrigation and for livestock are given in tables. The need for national guidelines on the use of sewage sludge in agriculture, and the polluting effects of aquaculture (fish farming and watercress growing) are highlighted. (AL)

395. Isirimah, N.O. and D.R. Keeney. 1973. Contribution of Developed and Natural Marshland to Surface and Subsurface Water Quality. Tech. Rep. 73-09. Wisc. Water Resources Center, Madison, WI.

396. Jacobs, S. A., and W. B. Kerfoot. 1976. Cadmium Accrual in Combined Wastewater Treatment-Aquaculture System. Environ. Sci. Technol. 10(7): 662-667.

Trace amounts of cadmium were added to isolated links of a sewage/sea-water-plankton-mollusc food chain in an experimental tertiary treatment-aquaculture system. Cd accumulation was studied in two types of phytoplankton (a green platymonad and a mixture of diatoms), and in two species of mollusc (American oyster and hard clam). Cd concentrations in algae increased rapidly until equilibrium was reached while molluscs showed a continuous accumulation when exposed to sea water and algae mixtures contaminated with Cd. Investigation of the pathways of accumulation in the food chain showed that although oysters and clams can absorb Cd direct from sea water, the principal source of accumulation is the algae. Human uptake of Cd through eating shellfish, and the rate of accumulation by age are discussed. Recommended levels of Cd in municipal effluent and diluent sea water used for aquaculture are calculated. (AL)

397. Janota, T., and O. L. Loucks. 1975. An Analysis of the Value of Wetlands for Holding Inorganic Phosphorus. Univ. of Wisconsin, Center for Biotic Systems. Madison, WI.

398. Jarman, R. 1976. Aquaculture as an Alternative Wastewater Treatment System, pp. 215-224. In J. Tourbier and R. W. Pierson, Jr. (eds.), Biological Control of Water Pollution. Univ. of Pennsylvania Press, Philadelphia, PA.

399. Jenkins, S. H. 1973. Advances in Water Pollution Research. Proceedings of the Sixth International Conference held in Jerusalem, June 18-23, 1972. Perg. Press Ltd. 895 pp.

This book contains seventy-one of the papers presented at the 6th conference organized by the International Association on Water Pollution Research, together with the subsequent discussions and replies. Sections are included on thermal pollution and oxygen transfer; trace metals in waters; microbiology and virology of wastewater; pollution of ground water; eutrophication and ecosystems; mathematical modelling; sewers and stormwater; sewage treatment; industrial effluents; advanced treatment and re-use of wastewaters; water management and water quality; and estuarine and marine problems. Author and subject indexes are provided. (AL)

400. Jenne, E. A., and S. N. Luoma. 1977. Forms of Trace Elements in Soils, Sediments, and Associated Waters: An Overview of Their Determination and Biological Availability, pp. 110-143. In H. Drucker and R. E. Wildung (eds.), Biological Implications of Metals in the Environment. Energy Research and Development Administration Symposium Series No. 42. Washington, DC.

401. Jetter, W. 1974. Animal Populations at Two Cypress Domes, pp. 537-588. In H. T. Odum, K. Ewel, and J. Ordway (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. First Annual Report to the National Science Foundation. Center for Wetlands, Univ. of Florida, Gainesville.

402. Jetter, W. 1975. Effects of Treated Sewage on the Structure and Function of Cypress Dome Consumer Communities, pp. 588-610. In: H.T. Odum, K. Ewel, and J. Ordway, and M.K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling and Conservation. Second Annual Report. Center for Wetlands, Univ. of Florida, Gainesville.

403. Jetter, W., and L.D. Harris. 1976. The effects of perturbation on cypress dome animal communities, pp. 577-653. In H.T. Odum, K.C. Ewel, J.W. Ordway, and M.K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report to the National Science Foundation. Center for Wetlands, Univ. of Florida, Gainesville.

Wildlife studies were conducted at three cypress domes located 8 km northwest of Gainesville, Alachua County, FL, during 1973-1976. Arthropods, amphibians, reptiles, birds, and mammals were sampled to determine their response to sewage treatment of the cypress domes. A chronology of events affecting the consumer communities; the methodologies employed, with types of sampling devices and techniques illustrated; and the results of the study are included. Food web structures were developed for a natural dome, a dome that received secondary treated effluent, and a dome that received effluent with a heavy organic load to show the major shifts in the energy flow pathways. (EP)

404. Jewell, W. J., R. M. Kabrick, J. J. Madras, and J. R. Bouzoun. 1981. Reclamation of Wastewater with Plants in Nutrient Films. Presented at the Water Reuse Symposium II. Washington, DC. August 23-28, 1981.

The present directions in wastewater treatment should emphasize maximum pollution control and the recovery of nutrients with minimum capital and energy investments. This is the first comprehensive report on a unique plant production system, which could lead to a new solarpowered pollution control/resource recovery system. It could serve as a major tool in achieving high water quality and resource recovery for the future.

The nutrient film technique (NFT) is a unique modification of a hydroponic plant growth system which utilizes plants growing on an impermeable surface. A thin film of water flowing through the extensive root system provides plant nutrients. Exceptionally high annual plant yields, 90 tons/ha-yr (40 tons/acre per year), and root mass up to 30 cm thick or more have been obtained. It was hypothesized that this self-generating plant system could be modified for use as a filter to immobilize and use the gross and trace organics in wastewater. The goal of this study is to determine the economic, technical, and practical feasibility of using plants grown in the NFT system as pollution control systems.

This feasibility study has been divided into two phases-a preliminary study to establish the potential of the system, and an additional 9-month test phase to be completed in June 1981, to enable additional variables to be evaluated in longer term plant growth tests. Three parallel testing programs were used: pure substrate definition of candidate species culturing practices and nutrient responses, synthetic polluted wastewater, and primary settled domestic sewage. These three substrates allow measurements of gross pollutant removal, as well as nutrient and trace organic removal kinetics. The three initial test systems, using a total of nine test units, were operated at daily application rates of 2.5 to 40 cm per day, and flow rates of more than 4000 liters per day.

The successful cultural experiments have produced, from seed or cuttings, viable stands of Reed Canary Grass, Coastal Bermuda Grass, Watercress, Napier Grass, and Cattails in a maximum of six weeks. The propagation of NFT Reed Canary Grass and its use in solar greenhouses that require little, if any, energy input anywhere in the U.S. has been successful.

At daily loading rates of 10 cm per day the effluent quality with primary settled sewage was often less than 10 mg/l for SS and BOD_5. The influent sewage temperature was 9°C. Estimated area needs of an NFT system designed for BOD and SS removal appear to be approximately 2 hectares per thousand cubic meters (20 acres per million gallons) of flow, whereas up to 10 times this amount may be needed to provide tertiary quality effluent. The latter portions of this study will include: additional plant yield information, valuable by-product recovery potential (food, fiber, energy and distilled water), and full scale system design and start-up requirements. (AA)

405. Johnson, R. R., and J. F. McCormick (eds.). 1978. Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. Proceedings of the Symposium, December 11-13, Callaway Gardens, Georgia. General Tech. Rept. WO-12. U.S. Forest Service, Washington, DC. 410 pp.

406. Jones, R.C. 1979. Design and Construction Aspects of the Houghton Irrigation Project. In: J.C. Sutherland and R.H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a Conference held 10-12 July 1979.

The unique feature about the Roscommon Township Treatment Facility, which is one of several in the Houghton Lake area, is that secondary effluent can be disposed of at that site by flood irrigation to seepage beds, irrigation fields, or a natural wetland of 600 acres which provides tertiary treatment.

Initial construction of wastewater facilities was begun in 1972 and all of the above facilities except for the marshland irrigation project were completed by 1974, however, it was anticipated previously that by 1978, additional irrigation areas would be required. Projections made in early 1970 indicated an additional 98 million gallons of irrigation capacity per year would be needed by 1988, and an additional 181 million gallons by 1998.

The most attractive alternative for additional irrigation areas was using a nearby State owned swamp for tertiary treatment. The cost for this method of providing additional irrigation area was much more attractive due to the considerable cost savings involved for purchasing of additional land and construction of the required facility.

The wetland was left in its natural state. It was decided to disperse the effluent through gated irrigation pipe. (AA)

407. Jones, R.A. and G.F. Lee. 1978. An Approach for the Evaluation of the Efficacy of Wetlands-Based Phosphorus Control Programs on Downstream Water Quality, pp. 217-243. In: M.A. Drew (ed.), Environmental Quality Through Wetlands Utilization. Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin. Tallahassee, FL. 243 pp.

The Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin Restoration Project has as one of its objectives a reduction of phosphorus transport from agricultural lands to nearby water-courses. Any project of this type with this objective should include an evaluation of the potential impact of the nutrient control program on downstream water quality. In the past several years, significant advances have been made in the ability to predict with a fair degree of reliability, the impact on a water body's water quality, of the control of phosphorus input to the waterbody by a certain amount. These predictions are based on the Vollenweider OECD eutrophication study modeling results where it has been found for a wide variety of water bodies located in Western Europe, North America, and Japan, that the phosphorus load to a water body normalized by its mean depth and hydraulic residence time, can be used to predict the average and maximum growing season chlorophyll concentrations, water clarity based on Secchi depth, and hypolimnetic oxygen depletion rates.

A discussion will be presented of the use of the OECD eutrophication study results to estimate the improvement in water quality which would be expected to result from the construction of wetlands in the project area. Particular attention will be given to the types of modifications of the OECD eutrophication modeling approach that may have to be made in order to apply this approach to the water bodies downstream from the project area. (AA)

408. Jones, R.D. and M.A. Hood, 1980. Effects of Temperature, pH, Salinity, and Inorganic Nitrogen on the Rate of Ammonium Oxidation by Nitrifiers Isolated from Wetland Environments. Microbial Ecology 6(4):339-347.

The transformation of nitrogen and its recycling are extremely important to the productivity of aquatic ecosystems. Although factors affecting ammonium oxidation in agricultural soils and sewage have been investigated, information on factors affecting nitrification in wetland environments is lacking.

Ammonium-oxidizing bacteria were examined in a freshwater marsh and in an estuarine bay over a 2-year period. Two predominant species of Nitrosomonas were consistently isolated, one from each environment. A closed culture, high cell density assay was used to determine the effects of temperature, pH, salinity, sodium, potassium, nitrite, nitrate, and ammonium concentrations on nitrification. Maximum oxidation of ammonium by the freshwater isolate occurred at 35 degrees C, pH 8.5, salinities of 0.3 to 0.5 percent sodium and potassium, and ammonium concentrations exceeding 0.5 grams per liter. The estuarine isolate exhibited maximum activity at 40 degrees C, pH 8.0, salinities of 0.5 to 1.0 percent sodium and potassium, and 0.2 grams of ammonium per liter. The sodium requirement of the estuarine isolate could be partially substituted by potassium, suggesting that the organism is a true estuarine bacterium. Salinities below 0.5 percent may severely reduce oxidation of ammonium by the bacterium in the estuarine environment. While nitrate had no significant effect on either isolate, certain combinations of ammonium nitrite were inhibitory, especially to the estuarine species. The data indicate that oxidation of ammonium by isolates from wetlands is influenced by pH and temperature and that estuarine nitrifiers may be more sensitive to and more extensively affected by salinity, ammonium concentrations, and nitrite than are isolates from fresh waters.

409. Jorek, N. 1977. Habitat Management Concepts Worked Out at the Sewage Farm Project at Muenster. Agnew Ornithology 5(2):57-108.

410. Joseph, J. 1978. Hyacinths for Wastewater Treatment. Reeves Journal. 56(2):34-36.

Secondary treatment of wastewater with water hyacinths produced significant reductions in impurities, coliforms, and heavy metals in pilot plant tests conducted by the National Space Technology Laboratory at Orange Grove, Mississippi. Biologically treated wastewater from a population of 5,000 was introduced into an 0.7-acre hyacinth lagoon which was four to five times smaller than the primary aerated lagoon. Retention times of 14-21 days in the lagoon reduced suspended solids by an average of 72%, total nitrogen by 60%, total phosphorus by 26%, BOD to below standard levels, and coliforms from 121,000 to 40,000/100 ml. In the absence of toxins or metals, the harvested hyacinths yielded up to 25% crude protein for supplemental animal feed. An acre of hyacinths, producing from 8-16 tons wet bio-mass/day, generated 3,200-6,450 cu ft of methane gas/day with 0.5 ton fertilizer as a by-product. The water hyacinths were effective in removing lead, mercury, cadmium, cobalt, nickel, silver, and phenols. Research is being conducted to expand the hyacinth belt north of 33 degrees latitude.

411. Jurdi, M. S., A. Acrea, and M. Soufi. 1981. Wastewater Reclamation by Hydroponic Plant Growth. Presented at the Water Reuse Symposium II. Washington, DC. August 23-28, 1981.

The feasibility of growing plants hydroponically in raw untreated wastewater for reclamation and reuse was investigated. A variety of plants (cucumbers, tomatoes, peppers, and lettuce) were successfully grown in the medium but required the addition of iron.

The yield of vegetative growth in the medium was about double that in half-strength Hoaglands nutrient solution. Monitoring macro-elements (e.g., nitrate, sodium, potassium, phosphate, calcium), and trace elements (e.g., zinc, copper, manganese) showed a substantial reduction in their concentrations in the medium. Reduction of the mineral content correlated exponentially with time to a specific conductivity level of (300/umohos/cm, 25°C) equivalent to that of tap water. Transplanting into the medium of seedlings at more advanced stages of growth substantially lessened the period required for reduction in the mineral content of wastewater. This reduction correlated significantly with the final dry weight of the plants at the 0.05 level (r=0.979). (This work is supported by grants from The National Council for Scientific Research, Beirut, Lebanon). (AA)

412. Jurriens, M., and G. J. Kaassen. 1980. I. Evaluation of the Possibilities and the Effects of Bypassing Water Along Marshy Areas, and II. Sediment Intake to Reduce Degradation in an Offtake Canal. Rept. No. 226. Delft Hydraulics Laboratory. The Netherlands.

413. Kadlec, J.A. 1962. Effects of a Drawdown on a Waterfowl Impoundment. Ecology 43:167281.

414. Kadlec, J. A. 1976. Dissolved Nutrients in a Peatland Near Houghton Lake, Michigan, pp. 25-50. In D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of a Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Held 10-11 May 1976 at the Univ. of Michigan, Ann Arbor.

The use of peatlands and other wetlands as tertiary sewage treatment systems depends in part on a knowledge of the nutrient dynamics. The studies of dissolved nutrients reported in this paper were designed to contribute to that knowledge. The objectives were threefold:

To establish the levels and variability of the principle dissolved nutrients as background for other studies;

To learn something of the causal mechanisms involved;

To estimate the impact of controlled fertilization on the concentrations of dissolved nutrients.

415. Kadlec, J. A. 1979. Nitrogen and Phosphorus Dynamics in Inland Freshwater Wetlands, pp. 17-41. In T. A. Bookhout (ed.), Waterfowl and Wetlands - An Integrated Review. Proceedings of a Symposium held at the 39th Midwest Fish and Wildlife Conference at Madison, WI, 5 December 1977. La Crosse Printing Company, La Crosse, WI.

1080. Kadlec, J.A. In press.

416. Kadlec, J. A., R. H. Kadlec, P. E. Parker, and K. R. Dixon. 1973. The Effects of Sewage Effluent on Wetland Ecosystems. Progress Rept. to the National Science Foundation for 1 July 1972 to 1 April 1973. Univ. of Michigan, Ann Arbor.

417. Kadlec, J. A., R. H. Kadlec, and C. J. Richardson. 1974. The Effects of Sewage Effluent on Wetland Ecosystems. Semi-Annual Rept. No. 1 to the National Science Foundation. Univ. of Michigan, Ann Arbor.

418. Kadlec, J. A., R. H. Kadlec, and C. J. Richardson. 1974. The Effects of Sewage Effluent on Wetland Ecosystems. Progress Rept. to the National Science Foundation 1 April 1973 to 1 March 1974. Univ. of Michigan, Ann Arbor.

419. Kadlec, R. H. 1975. Pilot Scale Irrigation Experiment - 1975; Preliminary and Partial Results. In R. H. Kadlec, C. J. Richardson, and J. A. Kadlec (eds.), The Effects of Sewage Effluent on Wetland Ecosystems. Semi-annual Rept. No. 4. Univ. of Michigan, Ann Arbor.

420. Kadlec, R. H. 1976. Surface Hydrology of Peatlands, pp. 5-24. In D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of a Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Held 10-11 May 1976 at the Univ. of Michigan, Ann Arbor.

Annual precipitation exceeds evaporation and drainage is relatively poor in peatlands. Throughflow is slow enough to permit peat deposition and permit growth of moisture-tolerant plants. Water depth, nutrient availability and climatic conditions combine with successional processes to determine the type of vegetation in a given wetland situation.

Any process which affects the water content of such an area will, in the long term, affect the character of the wetland. Large-scale addition of wastewater will tend to increase water depths, and at some scale, will produce an environment conducive to deep-water species such as cattail. It is necessary to understand and quantify the water budget of a given wetland in order that wastewater addition can be intelligently planned.

In July, August and September 1975, wastewater was added to a small site in the peatland. The pilot (10-acre) site is in a shallow depression, with a mean ground of 10.5 feet with respect to the datum point of 10.00 feet located at station Z-4. A "ridge" of elevation 10.75 feet along the 68-line effectively "dams" a 200-acre area enclosing the pilot area.

Wastewater addition amounted to 8 inches on 10 acres in 8 weeks. No level effects were observed in the test area during irrigation. Levels increased and decreased in accord with the rest of the peatland. There is a possible small increase in the water depth for the entire 200-acre locale, but the topography negates the possibility of cross-country dispersal. No increases in peatland outflow were observed. Based on the data, it appears that a major portion of the added water evaporated from the test locale.

Larger-scale additions of water will increase depths and throughputs. However, the flow of water added at up-gradient points will be uniform, and at the same linear velocity as that in the natural peatland. Thus, the added water will be in contact with the surface litter for a period of approximately 100 days. The amount of added evaporation, if any, will depend upon changes in the plant cover type and density, and in water level. (AA)

421. Kadlec, R. H., 1977a. Natural and Irrigation Hydrology of the Porter Ranch Peatland, pop. 198-229. In: C.B. DeWitt and E. Soloway (eds.), Wetlands Ecology,, Values, and Impacts. Proceedings of the Waubesa Conference on Wetlands held in Madison, WI, 2-5 June 1977. Institute for Environmental Studies, Univ. of Wisconsin, Madison.

422. Kadlec, R.H. 1977b. Pilot Scale Irrigation Hydrology, pp. 30-52. In: R.H. Kadlec, D.L. Tilton, and J.A. Kadlec (eds.). Feasibility of Utilization of Wetland Ecosystems for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent. Semi-Annual Rept. No. 5. Univ. of Michigan, Ann Arbor.

Over 10 million gallons of secondarily treated wastewater were pumped to a northern Michigan peatland and distributed via a 200 meter gated irrigation pipe during the period May-September 1976. The added water spread in an irregular concentric pattern, creating a very shallow mound of surface water. The area of the mound ranged upward from 40,000 m^2 at an average depth of about 3 cm, depending upon precipitation and evapotranspiration. The prevailing drought conditions created a dry soil condition surrounding the pumped water mound. A concentric elliptical ring compartment budget was developed to summarize details of water movement and storage. (AA)

423. Kadlec, R.H. 1979a. Monitoring Report on the Bellaire Wastewater Treatment Facility. Utilization Rept. No. 3. Univ. of Michigan, Ann Arbor.

424. Kadlec, R. H. 1979b. Monitoring Report on the Bellaire Wastewater Treatment Facility. Utilization Rept. No. 4. Univ. of Michigan, Ann Arbor. 48 pp.

Wastewater from stabilization lagoons is gravity-discharged during summer and autumn to a partially forested peatland at Bellaire, MI. The results of studies conducted over a five year period show good phosphorus and nitrogen removal. Some damage has occurred to trees.

425. Kadlec, R.H. (ed.). 1979c. Wetland Utilization for Management of Community Wastewater - 1978 Operations Summary. Report to the National Science Foundation. Univ. of Michigan, Ann Arbor. 107 pp.

426. Kadlec, R. H. 1979d. Wetlands for Tertiary Treatment. In P. E. Greeson, J. R. Clark, and J. E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. Proceedings of the National Symposium on Wetlands, Lake Buena Vista, FL. Am. Water Resour. Assoc., Tech. Publ. TPS79-2. Minneapolis, MN.

Current information on the performance of fresh water wetlands in tertiary wastewater treatment is reviewed. A significant potential for water quality improvement has been demonstrated at many sites. Different choices of wetland partitioning are examined and illustrated, including the entire ecosystem, transects, and plots. Various derived measures of performance are illustrated, and all have some merit. Time effects are explored on several scales. Diurnal, daily, annual, and geological variations are all important. Data are lacking in many categories, but further studies are clearly warranted. Digital computation is necessary to organize the available data and extrapolate to different times, sites, and management strategies. Design criteria are not yet available, but economics appear favorable. (AA)

427. Kadlec, R. H. 1979e. Performance of the Bellaire, Michigan, Wetland Treatment Facility. In J. C. Sutherland and R. H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July at Higgins Lake, MI.

The village of Bellaire (pop. 1,000) is located in the northwestern portion of Michigan's lower peninsula, on the Intermediate River, which flows into Lake Bellaire. To protect the lake from unnecessary nutrient loading, secondary and tertiary stage treatment of wastewater is achieved at a considerable saving to the village, by surface discharge onto a coniferous forest wetland. The design and method of discharge at Bellaire was intended to be as similar to Houghton Lake as possible. Despite a vegetational dissimilarity, nutrient removals from wastewater at Bellaire have been as efficient as at Houghton Lake.

Wastewater was pumped to the wetland during the summers of 1976 and part of 1977, and a gravity system was used thereafter. Data were acquired on water flows, water chemistry, and environmental factors during all three summers. Summer averages of total dissolved P ranged from 2.11 to 3.48 mg/l; while the wetland outfall ranged from 0.06 to 0.16 mg/l. This is a concentration reduction of 94-97%. Summer averages of dissolved N ranged from 1.94 to 10.84 mg/l; while the wetland outfall ranged from 0.04 to 0.61 mg/l. This is a concentration reduction of 91-98%. About one-third of these reductions are due to dilution. Water samples taken during late winter and early spring 1977 indicated a release of P equal to 1.02% of the total P added over the period March-November. (AA)

428. Kadlec, R. H. 1979f. Performance of the Houghton Lake, Michigan, Wetland Treatment Facility. In J. C. Sutherland and R. H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July at Higgins Lake, MI.

The Houghton Lake Wetland Treatment System was built and placed in operation during the first six months of 1978. An operation and maintenance plan has been developed, and the system operated successfully in the treatment of 65 million gallons of secondary wastewater in summer 1978.

Water depths in the irrigation area were approximately 10-20 cm, with patches of deeper water in isolated depressions. Nitrogen and phosphorus removal was typically 90% complete within 100 meters of the discharge. Chloride was mostly unaffected by passage through the wetland. Altered water chemistry persisted further downgradient in the deeper water areas. The water in the discharge area has recovered completely by mid-October. No dramatic changes in vegetation species composition occurred in this first year, but plant growth and chlorophyll content were increased within 30 m of the discharge. No large changes occurred in vertebrate use, but there were alterations in vertebrate species composition and abundance within 30 m of the discharge.

The Houghton Lake wetland is well suited for use as a tertiary treatment facility due to several natural features and functions: deep organic soils, low nutrient levels in the background water, high plant productivity, and slow water movement. (AA)

429. Kadlec, R. H. 1979g. Wetland Tertiary Treatment at Houghton Lake, Michigan, pp. 101-139. In R. K. Bastian and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC. EPA 430/9-80-006.

The effects of secondary treated wastewater applied to a peatland in central Michigan for five consecutive summers are documented in this report. The Houghton Lake wetland treatment system was built and placed in operation during the first six months of 1978 and has proved to be an effective means of nutrient removal. Numerous figures and tables are included in the report that explain the effects of the study on wetland hydrology, water quality, vegetation, soils, algae, vertebrate and invertebrate populations, and pathogenic organisms. (EP)

430. Kadlec, R. H. 1981a. Monitoring Report on the Bellaire Wastewater Treatment Facility. Utilization Rept. No. 5. Univ. of Michigan, Ann Arbor.

431. Kadlec, R. H. 1981b. Monitoring Report on the Bellaire Wastewater Treatment Facility. 1980. Wetlands Ecosystem Research Group, Univ. of Michigan, Ann Arbor. 56 pp.

Approximately 30 million gallons of effluent were discharged to a wetland treatment site at Bellaire, Michigan, during the period 4 June to 5 November 1980. Data on water flows, water chemistry and other environmental parameters were collected and analyzed. Concentration reductions of 90% total dissolved phosphorus and 91% dissolved nitrogen were achieved in passage of the water through the wetland.

A five year summary of data for the performance of the wetland is included. Gross removal of dissolved nitrogen remained stable at approximately 78%. Gross removal of phosphorus remained at 65%. As a consequence, the amount of phosphorus discharged to Lake Bellaire has remained at five times the background level in the natural wetland. (EP)

432. Kadlec, R.H. 1981c. How Natural Wetlands Treat Wastewater, pp. 241-254. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

The advanced treatment of wastewater consists of removing the last traces of dissolved and suspended materials, pathogens and perhaps other biota. A wetland provides a blend of the aquatic and terrestrial ecosystem functions which have been proven to remove these undesirable materials. The incoming waters, typically slow to creeping flow, provide settling time for suspended material. Physical filtration through litter material also can occur. The wetland produces detritus and algal debris, which partly contribute to the pool of suspended and suspendable solids.

Dissolved nutrients can be sorbed on soil surfaces in shallow waters if given sufficient time to reach that surface. Bacterial action, such as denitrification, can occur at these surfaces as well. Typically, phosphorus compounds sorb and precipitate but nitrogen compounds do not. Nutrients are also used by algae and vascular plants in formation of new tissues on a seasonal basis. Subsequent death and litter fall of all or some algae and plant parts (leaves) occurs. The litter then decomposes, releasing the stored nutrients. However, a small portion becomes a permanent component of the wetland soil. Algal decomposition is rapid (weeks), and the detritus is finely divided. Plant litter decomposition is slow (years), and the detritus is coarse.

Addition of nutrients builds a larger vegetative pool, and hence a larger litter pool. Significant amounts of material are required.

Other dissolved materials may be stored in the vegetative/litter pool, or sorbed, as well. Elements such as boron and sulfur display this behavior. Other elements, such as sodium and chloride, are passed through with little effect.

Bacteria of many kinds thrive in the wetland environment, including coliforms. This serves to confuse many health-related issues. Viruses appear to deactivate at variable rates, ranging from hours to weeks. More research is needed in these areas. (AA)

1081. Kadlec, R.H. 1983.

1082. Kadlec, R.H. In press.

433. Kadlec, R. H., and D. E. Hammer. 1980. Wetland Utilization for Management of Community Wastewater - 1979 Operations Summary, Houghton Lake Wetlands Treatment Project. Report to the National Science Foundation. Univ. of Michigan, Ann Arbor. 83 pp.

The Houghton Lake Wetland Treatment System operated successfully in the treatment of 65 million gallons of secondary wastewater in the summer of 1978, and 101 million gallons in 1979. Treated wastewater from a holding pond is pumped through a 12 inch diameter underground force line to the edge of the Porter Ranch peatland. The water is distributed evenly across the width of the peatland through small gated openings in the discharge pipe. Each of the 199 gates discharged approximately 16 gallons per minute, under typical conditions, and the water spreads slowly over the peatland. Results are presented under the following topic areas: system operation, hydrology, surface water chemistry, litter and soil, vegetation status and response, and algal productivity. (NT)

434. Kadlec, R. H., and D. E. Hammer. 1981. Wetland Utilization for Management of Community Wastewater - 1980 Operations Summary, Houghton Lake Wetlands Treatment Project. Report to the National Science Foundation. Univ. of Michigan, Ann Arbor. 76 pp.

435. Kadlec, R. H., D. E. Hammer, I. S. Nam, and J. O. Wilkes. Overland Flow in Wetlands. Presented at the 88th National Meeting, American Institute of Chemical Engineers, 1980.

436. Kadlec, R. H., D. E. Hammer, and D. L. Tilton. 1978. Wetland Utilization for Management of Community Wastewater. Status Rept. to the National Science Foundation. Univ. of Michigan, Ann Arbor. 59 pp. (Available as NTIS Report PB80-108228).

Studies resulting in high water quality of the Houghton Lake Wetland Treatment system are reported. This system successfully treated 65 million gallons of secondary wastewater in the summer of 1978 for use in irrigating the Porter Ranch wetland in Michigan. Field research at the wetland focused on: (1) Collection of data to establish a current picture of the ecosystem in the discharge area; (2) continuous monitoring of the response of the irrigation area to wastewater flow; and (3) continuation of fundamental field studies to better understand response mechanisms and wetland system limits. Specific aspects described include water chemistry, soil elevation sampling, vegetation analysis, algae studies, nutrient sorption, bacteria and virus assays, and census of vertebrates and invertebrates. Laboratory studies were conducted to measure the rates and extent of physiochemical sorption of ammonia, nitrate, and phosphate. (NT)

1083. Kadlec, R.H. and D.E. Hammer. 1982.

1084. Kadlec, R.H. and D.E. Hammer. 1983.

437. Kadlec, R. H., D. E. Hammer, D. L. Tilton, L. Rosman, and B. Yardley. 1978. Houghton Lake Wetland Treatment Project. First Annual Operations Report. Univ. of Michigan, Ann Arbor. 87 pp.

438. Kadlec, R. H., and J. A. Kadlec. 1979. Wetlands and Water Quality (Theme Paper), pp. 436-456. In P. E. Greeson, J. R. Clark, and J. E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. Proceedings of the National Symposium on Wetlands, Lake Buena Vista, FL, Am. Water Resour. Assoc., Tech. Publ. TPS 79-2. Minneapolis, MN.

Wetland waters interact strongly with the other biotic and abiotic components of the ecosystem. Every water quality parameter is altered by passage through a wetland ecosystem. Nutrients and other dissolved constituents, heavy metals, suspended solids, and bacteria move into and out of the wetland with entering and leaving waters. Their concentrations can be altered by uptake, cycling, and dilution. Studies have been made of the gross inputs, outputs, and storages within wetlands; as well as more detailed studies of the water, sediment, and floral compartments. To interpret the performance of a wetland in altering any water quality parameter, a knowledge of the hydrology of the wetland is required, along with data on concentrations, mass flow and storage of the constituent of interest. Wetland ecosystems are dynamic, with both stochastic and time varying effects being of great importance. Diurnal, seasonal, and historic time patterns are necessary for complete understanding. Nitrogen and phosphorus cycle from the water to the plants to the sediments in the wetland ecosystem, with net storage or release depending upon the site. Dissolved constituents, such as chloride, often pass through the system without much alteration. Heavy metals appear to be immobilized in many situations, as are pesticides and other refractory chemicals. Suspended solids play an important role in wetland functions, both by themselves and as transporters of other components. Although wetlands are microbially active, they appear to be intolerant of human enteric microorganisms. These ecosystems appear to function as dynamic buffers against external upsets. In many cases, they are capable of serving as disposal sites for treated wastewaters. In almost all areas, there is a need to expand the data base in order to gain a better understanding of wetland processes which affect water quality. (AA)

439. Kadlec, R.H. and J.A. Kadlec, 1974. The Effects of Sewage Effluent on Wetland Ecosystems. NSF-RANN Semi-Annual Report. Univ. of Mich. Ann Arbor, MI.

440. Kadlec, R. H., J. A. Kadlec, C. J. Richardson, and D. L. Tilton. 1975. The Effects of Sewage Effluent on Wetland Ecosystems. Semi-Annual Rept. No. 4. Univ. of Michigan, Ann Arbor. 197 pp.

The report is part of an ongoing study of the nutrient status of the surface and interstitial waters of peatlands in Michigan. The contact of influent water with mineral soil and the length of travel through peat after such contact are key factors in determining retention. The balance between influent ground water and rain water as sources of nutrients for plant growth are considered to determine the plant communities. This study has been directed at an examination of the major ecosystem components with a view to predicting and monitoring these changes. This report considers the dissolved nutrients of the peatland, their variation in time and space, and the impact of small scale nutrient additions. (NT)

441. Kadlec, R. H., C. J. Richardson, and J. A. Kadlec. 1974. The Effects of Sewage Effluent on Wetland Ecosystems. Semi-Annual Rept. No. 2 to the National Science Foundation. Univ. of Michigan, Ann Arbor.

442. Kadlec, R. H., C. J. Richardson, and J. A. Kadlec. 1975a. The Effects of Sewage Effluent on Wetland Ecosystems. Semi-Annual Rept. No. 3 to the National Science Foundation. Univ. of Michigan, Ann Arbor.

443. Kadlec, R. H., C. J. Richardson, and J. A. Kadlec. 1975b. The Effects of Sewage Effluent on Wetland Ecosystems. Semi-Annual Rept. No. 4 to the National Science Foundation. Univ. of Michigan, Ann Arbor.

Ongoing studies of the effects of sewage effluents in wetland ecosystems are reported, with particular emphasis on the nutrient status of the surface and interstitial waters of peatlands in Michigan. Specific topics covered include: the effects of simulated sewage effluent on the decomposition, nutrient status, and litterfall in a central Michigan peatland, the effects of simulated sewage effluents on the growth and productivity of peatland plants, pilot scale irrigation experiments, a statistical analysis of seasonal changes in biomass (standing crop new growth) of selected wetland species as influenced by nutrient additions, and studies of dissolved nutrients in Michigan peatland.

444. Kadlec, R. H., and D. L. Tilton. 1977. Monitoring Report on the Bellaire Wastewater Treatment Facility. Utilization Rept. No. 1. Univ. of Michigan, Ann Arbor. (Two versions: complete and abridged).

445. Kadlec, R. H., and D. L. Tilton. 1978a. Monitoring Report on the Bellaire Wastewater Treatment Facility. Utilization Rept. No. 2. Univ. of Michigan, Ann Arbor.

This report concerns a secondary and tertiary stage treatment of wastewater by the village of Bellaire, MI, by surface discharge of effluent onto a forested wetland. Water flows, water chemistry, and environmental data were collected for an 8 month period. Total dissolved phosphorus and nitrogen in the wastewater averaged 3.48 mg per liter and 4.95 mg N/liter during the discharge period. Concentrations of P and N in water leaving the wetland were 0.11 mg/l and 0.46 mg/l respectively. This represents concentration reductions of 97% TNP and 91% DN. (WE)

446. Kadlec, R.H., and D.L. Tilton. 1978b. Wastewater Treatment Via Wetland Irrigation: Nutrient Dynamics, pp. 153-170. In M. A. Drew (ed.), Environmental Quality through Wetlands Utilization. Proceedings of a Symposium held 28 February - 2 March 1978, at Tallahassee, FL. Sponsored by the Coordinating Council on the Restoration of the Kissimme River Valley and Taylor Creek-Nubbin Slough Basin. Tallahassee, FL.

The impact of discharging approximately 10 million gallons of secondary effluent into a 10 acre section of the Houghton Lake wetland is described. Element budgets showed that 99%, 95%, and 71% of the total input of nitrate and nitrite nitrogen, total dissolved phosphorus (TDP), and ammonia nitrogen, respectively, were immobilized within 30 meters of the discharge location. Element immobilization occurred by a combination of biological and physical processes.

The Bellaire wetland was monitored from 15 March through 21 November 1977 to determine water flows, water chemistry, and environmental data. TDP and TDN in the wastewater averaged 3.48 mg/l and 4.95 mg/l during the discharged period (27 May through 3 November). Concentrations in the water leaving the wetland were 0.11 mg-P/l and 0.46 mg-N/l. These represent concentration reductions of 97% TDP and 91% TDN. Water samples taken during late winter and early spring indicate a release of phosphorus equal to 1.02% of the total phosphorus added during the period March to November. (EP)

447. Kadlec, R. H., and D. L. Tilton. 1979. The Use of Freshwater Wetlands as a Tertiary Wastewater Treatment Alternative. CRC Critical Reviews in Environmental Control 9(2):185-212.

The use of wetlands for tertiary wastewater treatment is a feasible alternative in the proper circumstances. The constraints which apply have not been totally determined, but are likely to be very site-specific. Small communities with large adjacent wetlands might consider this alternative.

Wetlands appear to be strongly buffered against the stress of treated wastewater additions. Dissolved nutrients are effectively removed in many cases, and suspended solids are exchanged. The added water and nutrients have an impact on the ecosystem which varies from site to site. The plant and animal communities undergo changes which range from barely undetectable to dramatic.

448. Kadlec, R. H., D. L. Tilton, and J. A. Kadlec. 1977. Feasibility of Utilization of Wetland Ecosystems for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent. Semi-Annual Rept. No. 5 to the National Science Foundation. Univ. of Michigan, Ann Arbor.

This study details the effect of discharging approximately 10 million gallons of secondary effluent onto a 10 acre section of wetland. Total dissolved phosphorus (TDP), ammonia nitrogen, nitrate plus nitrite nitrogen, Cl, Na, Ca, Mg, K, Ni, Zn, Cu, Pb, COD, pH, alkalinity, hardness, and specific conductivity were measured in the effluent and in surface waters at various distances (30-225 m) from the discharge location. TDP, nitrate plus nitrite nitrogen, and pH in surface waters had returned to background concentrations within 30 m of the discharge. Alkalinity and hardness had decreased to background concentrations 50 m from the discharge point, while Cl, Ca, Mg, Na, and to a lesser extent, K, tended not to decrease with the distance as much as the more biologically active ions. COD was lower in the effluent than in the wetland's surface water. Element budgets showed that 99%, 95%, 71% of the total input of nitrate plus nitrite nitrogen, TDP, and ammonia nitrogen, respectively, were immobilized within 30 m of the discharge site. Equivalent immobilizations of the total input for K, Mg, Na, Ca, and Cl, were 69%, 42%, 39%, 32%, and 30% respectively. Element immobilization occurred through a combination of physical and biological factors. (WE)

449. Kadlec, R. H., D. L. Tilton, and B. R. Schwegler. 1979. Wetlands for Tertiary Treatment: A Three-Year Summary of Pilot Scale Operations at Houghton Lake. Report to the National Science Foundation. Univ. of Michigan, Ann Arbor, 101 pp. (NTIS No. PB 295 965)

The process of wetland tertiary treatment of sewage treatment plant effluent was studied. The site was a peatland located at Houghton Lake, MI. The goal was to discharge 100,000 gallons/day treated wastewater onto a test plot measuring 40,000 square meters. This area was a scale up of 1000 over the earlier test plots. Monitoring and research activity focused primarily on hydrology and water quality, with secondary emphasis on plant, soils, animals, algae, bacteria, and viruses. Criteria for stopping effluent discharge were developed. This report covers the field results related to the discharge of wastewater. The results indicate that this method is an effective means of nutrient removal. All nitrogen and phosphorus were stored or removed within a five acre area, at a discharge rate of 100,000 gallons per day. The maximum increase in water depth was 15 cm at the center of a single point discharge. Coliform bacteria were present in both the discharge and in the natural wetland in comparable numbers. No virus was transported to the wetland. The animal populations exhibited little response to the discharge. (NT)

450. Kaila, A. 1959. Retention of Phosphate by Peat Samples. J. Sci. Agri. Soc. Finland 31:215-225.

451. Kaminski, R. M., and H. H. Prince. 1981. Dabbling Duck and Aquatic Macroinvertebrate Responses to Manipulated Wetland Habitat. J. Wildl. Manage. 45(1):1-15.

Responses of breeding dabbling ducks (*Anatini*) and aquatic macroinvertebrates to experimental modifications of cover; water ratio and basin surface were investigated in 1977 and 1978 within an impounded whitetop rivergrass (*Scolochloa festucacea*) meadow on the Delta Marsh, south-central Manitoba. Three areal percentage ratios of emergent hydrophytes to open water (30:70, 50:50, or 70:30) and 2 basin treatments (mowing of existing emergents or scarification by rototilling) were tested. Between years, pair numbers of mallards (*Anas platyrhynchos*) and blue-winged teal (*A. discors*) declined, whereas pair numbers of northern shovelers (*A. clypeata*), gadwalls (*A. strepera*), and pintails (*A. acuta*) were comparable. The greatest density and species diversity of dabbling duck pairs occurred on 50:50 plot in both years. Only blue-winged teal and pintail pair densities in 1978 were greater on mowed than on rototilled areas. Within years, species diversity of dabbling ducks was unaffected by mowing or rototilling. More pursuit flights arose from 50:50 plots and mowed areas compared to alternative treatments. Composition and resource levels (abundance, biomass, and number of families) of aquatic macroinvertebrate communities varied within and between years in response to basin treatments. These results imply prescriptions for wetland habitat management. (AA)

452. Kamppi, Armas. 1971. Studies of Wastewater Disposal on Peatland Forest Basin Infiltration Systems Which were in Effect in Finland in 1970. National Board of Waters, Finland: Report A4. 120 pp.

453. Kappel, W. 1979a. The Drummond Project. *In*: J.C. Sutherland and R.H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI.

The Town of Drummond (pop. 270), in northwestern Wisconsin, recently built a sewage treatment facility to handle the community's septic wastes. Plans were initially developed for a three lagoon, secondary treatment system, with effluent discharge twice a year to the Long Lake Branch of the White River, a Class 1-A trout stream. The lagoon system was to be built on U.S. Forest Service land, and in reviewing the project's environmental assessment, the Forest Service suggested a tertiary treatment alternative in which a 27-acre peat bog would be used to remove inorganic nutrients before final discharge to this important trout stream.

This tertiary treatment system uses gated irrigation pipe to disperse the secondary sewage effluent across and through the upper layers of this black spruce/tamarack peat bog. Effluent is discharged to the bog in 100,000 gallon slugs based on climatic and bog hydrologic conditions during the ice-free period of the year.

Research on this system is based in four critical areas. Primarily, water quality changes are studied as the effluent moves from the secondary treatment lagoons, through the bog, and downstream to the Long Lake Branch. A second study of the productivity and mineral content of bog plants is being made to determine how the bog species react to the application of the sewage effluent. A companion study uses aerial and ground level stereo photography to study bog vegetation compositional changes due to effluent application. A third study will compare the density and diversity of population of reptiles, amphibians, birds, small mammals, and terrestrial invertebrates between the project area and a nearby control area. Finally, a water/nutrient budget will be developed combining bog hydrologic data and the above mentioned nutrient studies to determine how the bog reacts to these discharges.

454. Kappel, W.M. 1979b. The Drummond Project: Applying Sewage Lagoon Effluent to a Bog: an Operational Trial, pp. 83-89. In: R.K. Bastian and S.C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division Washington, DC. EPA 430/9-80-006.

Sewage effluent was introduced into this 10 ha spruce-sphagnum bog in northwestern Wisconsin in May 1979. Effluent was applied to the wetland surface twice each year (spring and autumn) using a gated irrigation pipe system. This report contains a description of the overall operation of the system and the studies being conducted at the site on water quality, vegetation, and animal populations. A water and nutrient budget study also has been initiated. (EP)

455. Kardos, L. T., and J. E. Hook. 1976. Phosphorus Balance in Sewage Effluent Treated Soils. J. Environ. Qual. 5:87-90.

Four field sites which have been irrigated with various levels of secondary treated sewage effluent for 9 to 11 years have been examined for phosphorus content in soil water extracted with suction lysimeters. The cornfield site on Hublersburg clay loam irrigated with effluent had an average P concentration of 0.329, 0.070, and 0.046 mg/liter in soil water at 15, 60, and 120 cm respectively compared to 0.043, 0.046, and 0.037 mg/liter, respectively, under an adjacent fertilized, but unirrigated control. Year round application of effluent including 2 years of effluent plus sludge to reed canarygrass (Phalaris arundinacea L.) on Hublersburg clay loam resulted in average soil water concentrations of 0.170, 0.100, and 0.052 mg/P/liter at 15, 60, and 120 cm, respectively.

In an abandoned field on Hublersburg clay loam where no P was removed by crops, P concentrations were 0.140, 0.103, and 0.0765 mg P/liter for the treated plot and 0.038, 0.047 and 0.042 mg P/liter for the control at 15, 60, and 120 cm, respectivley. Only the 15-cm depth had significantly higher P concentrations in the treated plot. A hardwood forest located on a Morrison sandy loam soil was irrigated year round. Phosphorus concentrations in soil water were 0.349, 0.080, and 0.087 mg/liter for the treated vs. 0.059, 0.039, and 0.039 for the control at 15, 60, and 120 cm, respectively. Leaching losses were calculated from concentration of P in soil water at 120 cm and from leaching volume which was rainfall plus irrigation minus potential evapotranspiration. Over all years of treatment no site had leaching losses of >3% of the total applied. (AA)

456. Kardos, L.T., W.E. Sopper, E.A. Myers,, R.R. Parizek, and J.B. Nesbitt. 1974. Ord. U.S. EPA

A 500,000 gallon per day supply of chlorinated, secondary treated wastewater was applied through sprinkler irrigation systems to a combined acreage of approximately 70 acres of cropland and forestland in variously located experimental plots on Hublersburg silt loam or clay loam soils or on Morrison sandy loam soil. The hydraulic loads tested ranged from one to six inches at weekly intervals. The effects of application of the wastewater to the land on crop yields and crop chemical composition were generally favorable for the two hydraulic loads tested, 1 and 2 inches at weekly intervals during the growing season, only, or year-round. Harvested crops removed important amounts of the two key eutropic nutrients, phosphorus and nitrogen. On the forested sites tree growth respons was beneficial except with red pine on the Hublersburg soil when 2 inches of wastewater was applied at weekly intervals during the growing season. N and P content of the harvested crops and forest foliage was generally increased by wastewater irrigation.

Nitrate nitrogen levels in water recharging through the soil at the four foot depth were less than 10 mg/l except in the growing-season-2-inch red pine on Hublersburg soil and the year-round-2-inch hardwood area on Morrison sandy loam soil when NO_3-N values were 2 to 4 times the U.S.P.H.S. limit.

Phosphorus concentration in the suction lysimeter water samples at a depth of four feet was no greater on wastewater treated areas than on untreated control areas even on the sandy loam soil. Passage through four feet of soil decreased P concentration 98 to 99% through the combined effects of soil and vegetation in the "living filter" system. Deep well samples adjacent to the Hublersburg soil area showed no changes in water quality from normal background values. One deep well completely surrounded by wastewater treated sandy loam soil showed higher NO_3 and CL^- concentrations in the fifth year of treatment but sill met U.S.P.H.S. drinking water standards.

Recharge benefit to two nearby University water supply wells was estimated to result in water table build-up equivalent to 2 to 6 feet after a 2 year period of recharge of 6.5×10^7 gallons per year on 43.5 acres.

Annual costs of a spray irrigation system to recycle wastewater through the land was estimated to range from $13 per year per E.D.U. for 1 MGD to $81 per year per E.D.U. for 10 MGD.

This report was submitted in fulfillment of Project No. 16080 DYJ under the partial sponsorship of the Water Quality Office, Environmental Protection Agency.

457. Katzenelson, E., and S. Kedmi, 1979. Unsuitability of Polio Viruses as Indicators of Virological Quality of Water. Applied Environmental Microbiology 37.

458. Keating, K.I. 1976. Interference by Blue-green Algae with Nutrient Recovery in Water-quality Control Schema: Management Implications, pp. 241-245. In: J. Tourbier and R.W. Pierson (eds.), Biological Control of Water Pollution. Univ. of Pennsylvania Press.

Nutrient-rich natural waters are usually dominated by blue-green algae. From the viewpoint of a food chain culminating in harvestable fish the blue-greens are among the least desirable primary producers in that most, or all, are considered unsatisfactory food sources for zooplankton. They become even less suitable for intentional cultivation when certain of their other characteristics are considered-e.g. many produce unpleasant odors and tastes in waters; some act as allergens, or toxins-for animals ranging from invertebrates to humans; some have recently been implicated as possible vectors for viruses, although the capacity to harbor viruses may provide a means to control blue-green algae. It is therefore essential develop the management information and techniques necessary either to control, or to eliminate, the blue-green algae.

However, there is strong evidence that the competitive advantage of the blue-green algae is based at least in part on an allelopathic capacity. (AA)

459. Keenan, C. 1979. Effect of a Desert Marsh System on the Fertility of Secondarily Treated Sewage Effluent Discharged into Lake Mead. Journal of the Arizona-Nevada Academy of Science, Vol. 14. 1979 Proceedings Supplement. Arizona State University, Tempe, AZ.

460. Keeney, D. R. 1973. The Nitrogen Cycle in Sediment-water Systems. J. Environ. Qual. 2:15-29.

The available literature on the fate of nitrogen in waters and sediments is reviewed. Emphasis is placed on the importance of N to aquatic productivity, the pathways leading to N gains or losses in aquatic ecosystems, and the availability of N in sediments to the overlying waters. Important biological reactions include N mineralization and immobilization, nitrification and denitrification, and N fixation. The effect of sediment properties, lake morphology and environmental factors (pH, temperature, dissolved oxygen, oxidation-reduction potential) on the pathways and rates of N turnover are considered. The mixing process in sediments appear to be the most important in releasing sediment-N to waters. Several facets of the N cycle in waters and sediments require further elucidation. Research needs are outlined.

461. Keeney, D. R., and R. E. Wildung. 1977. Chemical Properties of Soils in: Soils for Management of Organic Wastes and Wastewater. Soil Science Society of America. Madison, WI.

462. Kelley, R., and M.A. Harwell. 1983. Comparisons of Processions of Elements by Ecosystems: Nutrients (Draft Manuscript) In: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop, 23-25 June 1982, University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

463. Kemp, M. C., D. S. Filip, and D. B. George. 1978. Evaluation and Comparison of Overland Flow and Slow Rate Systems to Upgrade Secondary Wastewater Lagoon Effluent. Rept. No. Q-78-02. Utah Water Research Lab. Logan, UT. 70 pp.

To evaluate the effectiveness of overland flow treatment in upgrading secondary wastewater lagoon effluent, three 15 x 36 m plots on a 2.5 percent slope were constructed and sown for a high density vegetative cover using Reed Canary grass. Wastewater was applied to the upper end of each plot at rates of 7.5, 15, and 22.5 cm/week. Results from the overland flow system investigation were compared with similar data obtained the preceding year from an existing slow rate land application system on an adjacent site. Secondary effluent from the same lagoon system as applied to the slow rate system study water quality characteristics from both systems, site specific efficiencies were detailed. (NT)

464. Kerfoot, W. B., and S. A. Jacobs. 1974. Permissible Levels of Heavy Metals in Secondary Effluent for Use in a Combined Sewage Treatment-Marine Aquaculture System I. Monitoring During Pilot Operation, pp. 65-78. *In* Wastewater Use in the Production of Food and Fiber Proc. U. S. Environmental Protection Agency. Ada, OK.

465. Kerfoot, W. B., and G. A. Redmann. 1974. Permissible Levels of Heavy Metals in Secondary Effluent for Use in a Combined Sewage Treatment-Marine Aquaculture System II. Development of Guidelines by Method of Additions, pp. 79-101. *In* Wastewater Use in the Production of Food and Fiber-Proc. U. S. Environmental Protection Agency. Ada, OK.

466. Khalid, R. A., R. P. Gambrell, M. G. Verloo, and W. H. Patrick, Jr. 1977. Transformation of Heavy Metals and Plant Nutrients in Dredged Sediments as Affected by Oxidation Reduction Potential and pH. Vol. I: Literature Review. Contract Report D-77-4. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

The occurrence and chemistry of selected trace metals and plant nutrients in sediment-water systems were studied. The toxic and nutrient elements included in the study were Pb, Cd, Hg, As, Se, Cu, Zn, Mn, Fe, N, P, and S. Effects of pH and oxidation-reduction conditions on metal and nutrient chemistry were stressed. (AA)

467. Khalid, R. A., W. H. Patrick, Jr., and R. D. Delaune. 1977. Phosphorus Sorption Characteristics of Flooded Soils. Soil Science Society of Amer. Journal 41:305-310.

Surface soils representing Alfisols and Inceptisols were collected from various parts of Louisiana under rice (*Oryza sativa* L.) cultivation and incubated under oxidized (aerobic) and reduced (anaerobic) conditions for

2 weeks in a soil to 0.01M $CaCl_2$ solution ratio of 1:5. The release of native soil P and the sorption of added inorganic P was investigated under these conditions. The soils selected for study were characterized for clay content, total carbon, extractable P, pH, and oxalate-extractable Fe, soil properties associated with P sorption. The results show that generally more soil P was released under reduced than oxidized conditions, and this increase in soluble P under reduced conditions was significantly related to Bray No. 2 extractable P, clay content, and oxalate Fe. At high levels of added P, more P was sorbed under reduced conditions than under oxidized conditions in 14 out of 20 soils under study. However, in Midland fine sandy loam essentially all of added P was recovered in the equilibrium solution under both oxidized and reduced conditions, suggesting this soil had no capacity to sorb P. The relationship between P sorbed at 500 ug/g added P and oxalate-extractable Fe was described by fitting two linear curves with different slopes. In the reduced soil samples the slope of Region I (3,000 ug Fe/g) suggests that 5.4 Fe sorbed 1P and that this ratio did not change until all of the added P was sorbed. In the oxidized samples this ratio was about 16 Fe/1P for Region 1(4,500 ug Fe/g). The slopes for Region II of the linear curves for both reduced and oxidized samples were essentially zero. A closer relationship between P sorbed and oxalate extractable Fe under reduced conditions indicates that poorly crystalline and amorphous oxides and hydroxides of Fe play a primary role in P retention by flooded soils and sediments. A probable greater surface area generated by the transformation of oxyferric hydroxide to more reactive ferrous compounds may be responsible for greater P sorption under reduced conditions. (AA)

468. Kidlow, J., and J. E. Huguenin. 1974. Problems and Potentials of Recycling Wastes for Aquaculture. Mass. Inst. of Technology, Sea Grant Program, 74-27. Cambridge, MA.

The potentialities and problems of using thermal effluents and/or secondary sewage as inputs to marine aquaculture systems are discussed. Although marine aquaculture technology is relatively undeveloped, and the use of waste in such a system is even less developed, potential for such systems appears enormous. In the future, the growing demand on coastal zones for both waste disposal and food production can be met only by a sophisticated, well-managed system. Feed cost for raising fish and farm animals will probably continue to rise, making the use of recycled wastes for feed in an aquaculture process an economically attractive concept. Research on the safety of marine waste-food recycling may have to be government sponsored. Also, the economic viability of these systems has not been demonstrated. (EL)

469. Kiemerle, R. A., and W. R. Enns. 1968. Aquatic Insects Associated with Mid-western Waste Stabilization Lagoons. J. Water Pollut. Control Fed. 40:R31-R41.

470. King, D. L. 1978. The Role of Ponds in Land Treatment of Wastewater, pp. 191-198. In State of Knowledge in Land Treatment of Wastewater. Vol. 2. U. S. Army Corps of Engineers Cold Region Res. Eng. Lab. Hanover, NH.

Ponds used for storage or pretreatment of wastewater prior to terrestrial application significantly alter wastewater quality. Data from the Michigan State University Water Quality Management Facility (WQMF) indicate that significant permanent phosphorus reduction decreases markedly once benthic sediments are saturated with phosphorus but that excellent nitrogen removal continues.

Phosphorus concentrations within such ponds vary seasonally but significant permanent phosphorus removal should not be anticipated beyond the first two or three years of operation. Harvest of aquatic plants yields only about 10% removal of both phosphorus and nitrogen.

In wastewater ponds, aquatic plant growth leads to accelerated denitrification and increases pH to 10 or more causing large ammonia losses to the air during those periods of the year when algae and aquatic macrophytes are active. While this nitrogen loss to the atmosphere will be controlled by site-specific conditions of light availability and temperature and alkalinity of the wastewater, nitrogen concentration decreases in a logistic fashion as a function of detention time within the WQMF ponds yielding a 95% nitrogen reduction in 120 days. The rate of nitrogen removal, as gN/M^2/day, from these ponds is a linear function of nitrogen concentration.

In addition to marked nitrogen losses associated with aquatic plant growth, the ability of these plants to elevate the pH also leads to precipitation of a variety of heavy metals. Such alterations in wastewater should be included in design criteria whenever ponds are incorporated in land treatment of wastewater. (AA)

471. King, D. L. 1979. Some Ecological Limits to the Use of Alternative Systems for Wastewater Management, pp. 299-307. In R. K. Bastian and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division, Washington, DC.

A great variety of biological, chemical, and physical factors interact and feedback to set limits on the ability of natural ecosystems to process wastewater. An understanding of these ecological limits allows better design of alternative wastewater management systems which can be tailored to fit local environmental and wastewater conditions relative to local wastewater standards. Ecological interactions responsible for oxygen supply for BOD satisfaction, plant production, and nutrient removal and recycle by alternative wastewater systems are considered for aquatic ecosystems and combinations of aquatic and terrestrial ecosystems. (AA)

472. King, D. L., and T. M. Burton. 1979. A Combination of Aquatic and Terrestrial Ecosystems for Maximal Reuse of Domestic Wastewater, pp. 714-726. In American Water Works Association Research Foundation,

Proceedings of the Symposium Vol. 1 held 25 - 30 March 1979 in Washington, DC.

In the design of pond-land wastewater processing systems the best features of the ponds should be meshed with the best features of the land to yield a system which meets specific needs for wastewater management and reuse relative to soil type, terrestrial vegetative cover and climate of the individual region.

While the nitrogen stripping capacity of ponds allows wastewater application to land on which the vegetative cover is inefficient at nitrogen removal, it can limit both attempts to reuse wastewater nutrients and attempts to maintain harvestable fish populations in the ponds. Where the goal is to maximize wastewater nitrogen recycle through terrestrial crops, ponding of wastewater should be minimized, particularly during the summer months, to prevent nitrogen loss prior to land application. When wastewater is stored over the winter and applied to the land during the summer, considerable nitrogen loss will occur as a function of detention time in ponds, particularly during the warmer months of the year. Nitrogen limitation of aquatic plants to types which cannot be harvested allows accumulation of significant BOD which, when exerted, is detrimental to any fish in the pond. (AA)

473. Kitchens, W.M., Jr., J.M. Dean, L.H. Stevenson, and J.H. Cooper, 1975. The Santee Swamp as a Nutrient Sink, pp. 349-366. In: J.B. Gentry, and M.H. Smith (eds.), Mineral Cycling in Southeastern Ecosystems. ERDA Symposium Series Conference - 740513.

The Upper Santee Swamp, South Carolina, extending from the confluence of the Congaree and Wateree Rivers, was studied for its role in the reduction of nutrient loads and fecal coliforms. The two rivers are heavily polluted from sewage discharges and agricultural runoff but Lake Marion, an impoundment five miles downstream of the Rivers' confluence has not shown eutrophication symptoms typical of shallow impoundments receiving comparable nutrient loads. The general trend observed, for both total and reactive phosphates, a 50% reduction in concentrations as the water passed from the rivers to the lower swamp provinces, depending on flow. Nitrate concentrations, consistently high in both rivers, was essentially unaltered in passage through the swamp. The flow through the swamp during the study period was usually a mass sheet over the floodplain floor, with no additional stream runoff inputs. Therefore concentration changes are definitely not due to dilution. The nutrient sink is considered primarily biological, with possible total phosphates adsorbed to suspended silts and clays. There was also a significant reduction in bacterial counts, including fecal coliforms, with little or no oxygen depletion as the waters coursed over the swamp.

474. Klafter, R.D., and W.E. Mattis. Optimal Waste Discharge in Estuaries and Bays. Presented at the IFAC Congress. Paris. June 12-17, 1972.

475. Klein, R.L., Jr. 1976. The Fate of Heavy Metals in Sewage Effluent Applied to Cypress Wetlands. Master's Thesis, Department of Environmental Engineering Sciences, University of Florida, Gainesville. 151 pp.

476. Klemetson, S. L., and G. L. Rodgers. 1981a. Evaluation of Biofilter Water Reuse Systems for Macrobrachium rosenbergii Prawn Aquaculture Ponds. Presented at the Water Reuse Symposium II. Washington, DC. August 23-28.

The yield of food protein from domestic aquaculture and its relative importance as a food source of human nutrition is rapidly rising. The interest in the commercial culture of Malaysian prawns, Macrobrachium rosenbergii, is steadily moving in the direction of intensification and the use of industrial methods. Additionally, since the prawn is a warm weather animal which requires a temperature of approximately 87°F (30°C), efforts are being made to protect the pond surface and maintain the proper temperature profile.

Water quality maintenance is the primary technical factor limiting the intensification of closed system aquaculture. Good water quality can theoretically be maintained by pass through biological filters where bacterial polycultures oxidize the toxic wastes, rendering it fit for reuse. The nitrogenous wastes are the most important task of the biofilters. The biofilters must operate in conditions that vary zero to 12 ppt of salinity, and with temperatures near 87°F (30°C).

The research on the treatment of fresh and saline wastewaters with a rotating biofilter has been completed, and the systems have produced good removal efficiencies using synthetic wastewaters for aquaculture pond wastewaters. Current studies involve live juvenile and adult prawn connected to the biofilter system. Concurrently, nitrogen compound toxicity studies are being conducted. The adult toxic limit is approximately 26 mg/l total available nitrogen, however, the biofilter systems can achieve effluent levels for biofilter reuse system at approximately 1 mg/l.

Current research is being conducted in the area of packed biological towers for both nitrification and denitrification of the heated, fresh and saline wastewaters produced by the live prawn aquaculture systems.

The paper will compare the cost and efficiency of several types of biological filter systems for direct aquaculture water reuse. (AA)

477. Klemetson, S.L. and G.L. Rodgers. 1981b. Biological Filters. J. Water Pollut. Control Fed. 53(6):687-699.

478. Klock, J. W. 1971. Survival of Coliform Bacteria in Wastewater Treatment Lagoons. J. Water Pollut. Control Fed. 43:2071-2083.

The survival of coliform organisms in domestic wastewater was studied under field conditions using a specially constructed channeled lagoon 4,000 ft. (1,218 m) long. The lagoon was continuously fed with partially settled raw wastewater, and the sequence of physical, chemical, and biological events comprising the transformation of raw waste to a treated wastewater was studied in conjunction with the measurement of coliform survival. Coliform die-away was observed to be of simple exponential form, $N_1=N_0 10^{kt}$, where N is the number of organisms at times 0 and t and k is a rate constant. The influence on k of temperature (T), oxidation-reduction potential (Eh), and pH was evaluated. (AA)

479. Klopatek, J. M. 1974. Production of Emergent Macrophytes and their Role in Mineral Cycling within a Freshwater Marsh. Master's Thesis. Department of Botany, Univ. of Wisconsin. Milwaukee. 278 pp.

480. Klopatek, J. M. 1975. The Role of Emergent Macrophytes in Mineral Cycling in a Freshwater Marsh, pp. 367-393. *In* F. G. Howell, J. B. Gentry and M. H. Smith (eds.), Mineral Cycling in Southeastern Ecosystems. U.S. Energy Research and Development Administration Symposium Series (CONF-740513).

Thersa Marsh, Wisconsin, was investigated by examining both the ontogeny of the species and their patterns of nutrient uptake and release. Three variable linear regression equations were employed to compare the changes in the amount of nutrients (G/SQ M) in the belowground and the aboveground standing crops and the level of soil nutrients in monotypic stands of *typha latifolia*, *scirpus fluviatilis*, and *carex lacustris*. The highly significant correlation values between both *scirpus* and *carex* (and to a lesser extent *typha*) and total soil nitrogen was somewhat surprising since, in continually waterlogged soils, ammonia is regarded as the sole plant-available nitrogen. The magnitude of correlations with phosphorus indicated that the emergent macrophytes are perhaps the factor controlling the flux of phosphorus in the soil during the growing season. Total nitrogen and available phosphorus in the marsh soil appear to be adequate; the macrophytes are acquiring their nutrients from the soil, and control the nutrients within the soil during the growing season. Denitrification reactions appeared to occur throughout the year, especially during summer. Potassium, calcium, and magnesium concentratins throughout the year appeared dependent on the macrophyte uptake and leaching losses, total respiration in the marsh, and the physical and chemical characteristics of the water.

481. Klopatek, J. 1978. Nutrient Dynamics of a Freshwater Riverine Marsh and the Role of Emergent Macrophytes, pp. 195-216. *In*: R.E. Good, D.F. Whigham and R.L. Simpson (eds.), Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, New York.

The open characteristic of freshwater riverine marshes results in a combined subsidy and withdrawal of nutrients, with the specific patterns in a given wetland being dependent on seasonal hydrological fluctuations and biological activity. A key feature of the marsh separating it from terrestrial ecosystems is its inundated and anaerobic soils which show statistically significant ($P<.01$) seasonal variations in available P and K and exchangeable Ca and Mg. Based primarily on investigations in Wisconsin, the role of emergent macrophytes within the marsh nutrient cycle is described. Concentrations of N,P,K,Ca, and Mg are shown to follow predictable trends over the macrophyte growing season. Regression analyses revealed nutrient update by the macrophytes was significantly correlated ($r^2 = .98, P<.01$) with total soil N and available P. For the most part, significant correlations were not present for the other elements. This is explained by their mobility and the possibility of luxury uptake. Models of the flow of nutrients in a *Scirpus fluviatilis* stand are depicted. The effects of a marsh drawdown on the nutrient cycle and nutrient dynamics of *Salix interior*, a typical riverine marsh shurb, are also discussed. (AA)

482. Knighton, M.D., and D.E. Streblow. 1979. Study Plan: Changes in a Bog Community Following Application of a Secondary Lagoon Effluent. Unpublished report. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, Grand Rapids, MI. 11 pp.

The research planned at this site includes measurements of species composition changes that may occur as a result of wastewater applications. Field methods such as low and high level photography of permanent quadrats, ground truthing, vegetation mapping, and other techniques are described.

483. Kok, T. 1974. The Purification of Sewage from a Camping Site with the Aid of a Bulrush Pond. H_2O 7(24):536-544.

484. Konefes, J.L., and R.W. Bachman. 1970. Growth of the Fathead Minnow (*Pimephales promelas*) in Tertiary Treatment Ponds. Iowa Acad. Sci., 77:104-111.

485. Kothandarman, V., and R.L. Evans. 1972. Removal of Algae from Waste Stabilization Pond Effluents. State of the ARt. Ill. Water Surv. Circ., 108 pp.

486. Kowal, N.E., and H.R. Pahren. 1981. Health Effects Associated with Wastewater Treatment and Disposal. J. Water Pollut. Control Fed. 52(6): 1312-1325.

487. Kramer, J.R., S.E. Herbes, and H.E. Allen. 1972. Phosphorus Analysis of Water, Biomass and Sediment, pp. 51-100. *In* H.E. Allen and J.R. Kramer (eds.), Nutrients in Natural Waters. John Wiley and Sons, New York.

488. Krapu, G. L., D. R. Parsons, and M. W. Weller. 1970. Waterfowl in Relation to Land Use and Water Levels on the Spring Run Area. Iowa State Journal of Science 44:437-452.

489. Krauss, A. P. 1979. Design Involvement Leads to Public Acceptance. Water and Wastes Engineering 16(11):50-52.

The design and construction of the new advanced wastewater treatment plant at Greenville, Maine, is described with tables and diagrams. The facility uses the Marsh Farm land application system for wastewater treatment and disposal, and comprises aerobic/facultative treatment of wastewater to a secondary level, followed by storage in a lagoon system ready for spray irrigation from May to November. (AL)

490. Krebs, C. T., and I. Valiela. 1978. Effects of Experimentally Applied Chlorinated Hydrocarbons on the Biomass of the Fiddler Crab, *Uca pugnax*. Estuar. Coast. Mar. Sci. 6:375-386.

491. Krebs, C. T., I. Valiela, G. Harvey, and J. M. Teal. 1974. Reduction of Field Populations of Fiddler Crabs by Uptake of Chlorinated Hydrocarbons. Mar. Pollut. Bull. 5:140-142.

492. Krishnamoorthi, K. P., and M. K. Abdulappa. Domestic Wastewater Utilization Through Aquaculture Studies at Nagpur, India. Presented at IAWPR Developments in Land Methods of Wastewater Treatment and Utilization Intl. Conf. Melbourne, Australia. Oct. 23-27, 1978.

In Nagpur City, India, domestic sewage is being treated in stabilization ponds. A four year study was conducted to examine algal ecology, productivity, and operational and biological parameters in the system. Results indicated that the system achieved a very large reduction in pathogenic load, recycled domestic wastewaters efficiently, and yielded many useful by-products. The relative low cost of stabilization ponds makes them a viable economic proposition. (EL)

493. Krull, J.N. 1970. Aquatic Plant Macroinvertebrate Associations and Waterfowl. Journal of Wildlife Management 34(4):707-718.

494. Krupauer, V. 1971. The Use of Herbivorous Fishes for Ameliorative Purposes in Central and Eastern Europe, pp. 95-103. *In* Proc. Eur. Weed Res. Counc. 3rd Int. Symp. Aquat. Weeds.

495. Kruse, H. 1962. Some Present-day Sewage-treatment Methods in Use for Small Communities in the Federal Republic of Germany. Bull. of the World Health Organization 26:542-549.

496. Kruzic, A. P. 1979. Water Hyacinth Wastewater Treatment System at Disney World, pp. 257-272. In R. K. Bastian and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. U. S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC.

In general all of the components of the project are operating as planned but there have been problems. For example, when the ponds were first seeded the hyacinths were hand picked and placed into the channels. This was too slow, so a backhoe was used to finish the seeding. This was a mistake because a great deal of dollarweed and grass was brought in with the hyacinths. Some of the unwanted species were removed but total segregation was not possible. The unwanted plant species were harvested out of the system only after much effort.

The only major concern at this time is whether or not the system can effectively handle primary effluent. The dissolved oxygen concentrations are very low, floating sludge in the open areas has appeared and there are many fly larvae where the ponds once flourished with thousands of mosquito fish. Fortunately mosquitoes have not been a problem so far.

In summary, the hyacinth project at WALT DISNEY WORLD is still in the process of start up. The scope of the project is quite large and there are many details to be worked out. The system is unique in its attempt to provide all the data needed by engineers to design a water hyacinth wastewater treatment system. (AA)

497. Kuenzler, E. J. 1971. Aspects of Phosphorus Cycling in Brackish Waters. Univ. of North Carolina, Chapel Hill. 50 pp. (NTIS ORO-3549-7)

In this study the consequences of subjecting small brackish water ecosystems to domestic sewage was investigated. Six ponds, three receiving municipal sewage wastes, were regulated with seawater, freshwater and sewage to control salinities and retention time. The ponds were seeded with larvae and microscopic plants, fish, and invertebrates. Measurements of temperature, salinity, insolation, plant nutrients, standing crop, and metabolic rate were taken for a two year period. The ponds acted as tertiary treatment or oxidation ponds and prevented the deterioration of the quality of receiving water. The study indicates that reasonable amounts of sewage waste may not prove harmful to functioning brackish ecosystems. (WE)

498. Kuenzler, E. J., and A. F. Chestnut. 1971. Structure and Functioning of Estuarine Ecosystems Exposed to Treated Sewage Wastes. Institute of Marine Sciences, Univ. of North Carolina, Morehead City, NC. 346 pp.

This is the third annual report from an investigation of the ecological systems which develop when estuarine waters are enriched with sewage wastes. Faculty and students from the University of North Carolina have studied various phases of community structure and metabolism of six experimental brackish water ponds, three of which receive treated sewage wastes, and of a small tidal creek and its salt marshes. In this report are chapters on productivity, carbon metabolism, the phosphorus budget, nitrogen, and bacterial heterotrophy; on the standing crops of phytoplankton, decapod crustaceans, fishes, meiofauna, foraminifera, insects, molluscs, and birds; on calcium analysis; and on growth and reproduction of algae. The waste ponds have developed into productive, well-integrated, but slightly unstable systems. They perform some of the functions of tertiary treatment and hold promise for production of harvestable seafood protein. (NT)

499. Kuenzler, E. J., W. Laughinghouse, J. A. Marsh, M. S. May, and H. N. McKellar. 1971. Structure and Functioning of Estuarine Ecosystems Exposed to Treated Sewage Wastes. II. Inst. of Marine Sciences. Univ. of North Carolina. Morehead City, NC. 53 pp.

Contents: Insolation, pH, and turbidity; notes on hydrography and phytoplankton of Calico Creek; direct bacterial counts; micro-organism diversity study of the two sets of ponds at Morehead City, North Carolina; excretion of dissolved organic phosphorus by plankton. (NT)

500. Kuenzler, E.J., A.F. Chestnut, and C.M. Weiss. 1973. Structure and Functioning of Estuarine Ecosystems Exposed to Treated Sewage Wastes, III. 1971-1972. Sea Grant Rept. No. 73-10. Univ. of North Carolina. Chapel Hill, NC. 228 pp.

This is the fifth report of investigations of the ecological systems which develop in small brackish-water ponds enriched with secondarily treated domestic sewage. Six ponds were built, three of which received sewage wastes from the town of Morehead City, North Carolina. In essence, the waste ponds were tertiary treatment or oxidation ponds. Brackish oxidation ponds have seldom been studied and consequently there was a need to examine, insofar as possible, the entire system, the physical factors, the water chemistry (especially plant nutrient), the plant and animal populations which developed, the metabolic processes of the pond systems, the effects of the pond system on water quality, and the aquaculture potentials. (NT)

501. Kuenzler, E.J., P.J. Mulholland, L.A. Ruley, R.P. Sniffen. 1977. Water Quality in North Carolina Coastal Plain Streams and Effects of Channelization. North Carolina Water Resources Research Institute, Raleigh, NC. UNC-WRRI Rpt. No. 127. NTIS No. PB-278 273. October. 160 p.

The physical and chemical characteristics of seven small Coastal Plain streams of eastern North Carolina were studied. Three natural streams which flow through relatively undisturbed bottomland hardwood forests were compared to four streams which had been channelized for the purpose of reducing agricultural losses caused by flooding. Two or three sampling stations were established on each stream. Some stations on natural streams were essentially pristine but others received point-source inputs of livestock farm wastes. The natural streams had broad floodplains and low stream velocities even during flood stages. Spates occurred in all seasons, but high discharge, and concomitant flooding of natural swamps, were usually greatest during winter and spring. The waters of channelized streams, however, were restricted: they attained higher velocities, carried greater particulate loads, and were more turbid than natural streams. Some channelized streams were enriched by sewage, by livestock wastes, or by agricultural fertilizer. Weighted mean concentrations of the nutrient element N and P were much lower in waters in unpolluted natural streams than in rainwater, and there was a net input of these nutrients to the watershed. Concentrations and fluxes of elements such as Ca, Mg, Na, K, and Cl, however, were higher in all streams than in precipitation and the net fluxes of these elements were directed out of the watershed.

502. Kuo, S. and D.S. Mikkelsen. 1979. Distribution of Iron and Phosphorus in Flooded and Unflooded Soil Profiles and their Relation to Phosphorus Absorption. Soil Science 127:18-25.

Phosphorus adsorption was investigated in two, paired soil profiles-flooded rice and irrigated pasture-to elucidate changes of phosphorus as a consequence of long term seasonal soil flooding. In the two concentrations studied, 10 and 50 ppm P, the adsorption of phosphorus was considerably higher in the flooded rice topsoils, 0 to 30 cm in depth, than in the upland topsoils. The difference in phosphorus adsorption gradually decreased as soil depth increased. High phosphorus adsorption in the rice topsoils was attributed to the higher content of amorphous iron resulting from reduction caused by seasonal soil submergence.

Fractionation of phosphorus in the soil profiles revealed that prolonged seasonal flooding tends to increase the 0.1 N N_aOH-extractable phosphorus and, concomitantly, to decrease the reductant soluble and calcium phosphate contents. The lower pH and reductive conditions prevailing in the flooded rice soils appear to be responsible for the transformations of calcium and crystalline iron phosphates to amorphous types of phosphate precipitates.

No significant eluviation of iron or phosphorus was observed in the flooded rice, as compared with adjacent pasture soils. The high clay content of these soils, coupled with a virtual lack of water movement through the profiles, may restrict the movement of these two elements. (AA)

____. Kusler, J.A. 1980.

____. Kusler, J.A. 1983.

503. Kutty, M.N., 1980. Aquaculture in Southeast Asia: Some Points of Emphasis. Aquaculture. 20(3):159-168.

Some aspects of aquiculture in Asia are reviewed, with emphasis on the need for increased production of cheaper animal protein. The Eastern cultures have generally been more advanced in the commercial growing of aquatic species. Aquiculture is practiced in developing countries mainly to provide organisms to serve as food and to recycle organic wastes. The priorities of current aquiculture programs, which are supported by many international organizations, are discussed. The use of sewage as a nutrient source in fish culture systems has been practiced in several Asian countries. Controlled eutrophication has given high production rates with caged fish in Indonesian streams, and the polyculture of carp has been tested in sewage-fed ponds in India. Fish raised on sewage must be examined thoroughly for pathogens before they are deemed fit for human consumption. Semi-cultural conditions of fish growing using oceans and man-made reservoirs may also be profitable. The abiotic factors affecting fish reproduction and growth must be carefully controlled. Behaviorial patterns of fish should also be studied to optimize fish growth and prevent wasting of energy derived from food. Other areas of aquiculture that require further research are the genetic improvement of species used for breeding and fish food sources.

504. Lackey, J.B. 1967. Nutrient and Pollutant Response of Estuarine Biotas. In: Proc. Natl. Symp. Estuarine Pollution. Aug. 23-25, 1967.

The behavior of microbiota, algae and protozoa, as affected by commercial, recreational, and metropolitan uses of estuarine waters are outlined. Some of the findings include: 1) estuaries and bays are of great economic and recreational value as nurseries, fishing grounds, shellfisheries, and boating and bathing areas, 2) human activities often modify the preferred ecology by adding nutrients or pollutants, 3) the suspended microscopic plants and animals (plankton), and those of the interface (benthos) are most easily studied qualitatively and quantitatively, 4) some pollutants, such as silt, sharply reduce the microscopic populations, and 5) the role of the engineer in estuarine studies is seeing that adequate biological studies are made so adequate treatment facilities will prevent overenrichment or pollution. (WE)

505. Lakshman, G. 1979. An Ecosystem Approach to the Treatment of Waste Waters. J. Environ. Qual. 8(3):353.

Aquatic plants such as bulrush (Scirpus spp) and cattail (Typha spp) were used to purify untreated municipal sewage in experimental tanks in a growth chamber measuring 5.5 by 3.7 by 3.7 m high. Initial concentrations of total phosphorus (TP) and total Kjeldahl nitrogen (TKN) before treatment ranged from 3.9 to 29.0 ppm for TP and from 10.3 to 44.0 ppm for TKN. Rates of removal of phosphorus and Kjeldahl nitrogen by the plants were monitored and compared with a control without plants. Generally, the concentrations of TP and TKN decreased exponentially in the treatment trays during the individual experimental runs. High rates of purification, up to 98%, were achieved in <20 days. During the 20 experimental runs lasting >500 days the plants showed unabated ability to remove nutrients while the control achieved a saturated condition.

Rates of nutrient uptake by the experimental plants increased with the ambient concentration and were much faster than the rates predicted by Michaelis-Menten kinetics. Above-water biomass obtained by periodic harvesting showed that the plants contained high levels of digestible organic matter (DOM) and crude protein comparable to the values obtainable from alfalfa. Experimental data have been used in develop equations for large-scale in situ applications. Data presented here show that aquatic plants have considerable potential in the purification of municipal waste waters within reasonably short periods.

506. Lakshman, G. 1980. A Demonstration Project at Humboldt to Provide Tertiary Treatment to the Municipal Effluent Using Aquatic Plants. 1979 Progress Report. Saskatchewan Research Council. Saskatoon, Saskatchewan, Canada, 67 pp.

507. Lalancette, J.M., and B. Coupal. 1972. Recovery of Mercury from Polluted Water through Peat Treatment, pp. 213-217. In: Fourth Int. Peat Cong. Proc. Ontaniemi, Finland.

508. Lance, W.R. 1971. Use of Tertiary Treated Water for Waterfowl Habitat Fish Rearing Facilities. Master's Thesis. Colorado State University.

509. Larsen, J.E., G.F. Warren, and R. Langston. 1959. Effect of Iron, Aluminum, and Humic Acid on Phosphorus Fixation by Organic Soils. Soil Sci. Soc. Amer. Proc. 23:438-440.

510. Larson-Albers, C.E. 1981. The Effects of Wetland and Drainage Ditch Outputs on the Water Quality of a Stream in South Central Minnesota, pp. 181-198. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

To form a baseline study of a proposed county ditch, nutrient levels (PO_4-P, TKN and NO_3-N) were monitored during 1980 at eight sites along the stream proposed to be channelized. Tributaries from three partially drained wetlands and four drainage ditches were also sampled to compare wetland and ditch outputs and to assess their impact on the stream's water quality. The 4554-acre watershed of the stream was dissected into the tributary subsheds and percentage of different land use categories, numbers of animal units, and tiling histories were compiled and examined for relationships to water chemistry differences.

From the significant differences found in nutrient concentrations among sites, it was possible to form a wetland-to-ditch continuum bounded at either end by the most distinct wetland (PO_4-P, TKN, and NO_3-N means of .919, 3.42, and 0.24 ppm) and the most distinct ditch (PO_4-P, TKN, and NO_3-N means of .112, 1.32, and 8.75 ppm). In the spring, one wetland of the three studied and two in the summer were significantly different from drainage ditches with higher levels of PO_4-P and TKN and lower levels of NO_3-N. Differences among the other sites were based primarily on nitrate levels in which the wetlands as a group could be separated by their lower concentrations from the ditches. Land use possibly contributes to these differences, as a lower row crop-to-wetland ratio in the watershed of a tributary corresponds to more wetland-like chemistry in the outlet.

511. Lazio, T. 1972. Reeds Control Eutrophication of Balaton Lake. Water Research 6:1533-1539.

The effects of sewage from a water treatment plant on Lake Balaton, Austria, was studied. A comparison was made of the effect of effluent that flowed through reeds versus the effluent that flowed directly into the lake. The effluent passing through the reeds had hardly detectable amounts of nitrogen and phosphorus. (WE)

512. Lee, C.R., et. al., 1976. Feasibility of the Functional Use of Vegetation to Filter, Dewater, and Remove Contaminants from Dredged Material. U.S. Army Corps of Engineers Environmental Laboratory, Tech. Rept. D-76-4 NTIS No. AD A028336.

513. Lee, C.R., B.L. Folsom, Jr., and R.M. Engler. 1980. Availability and Plant Uptake of Heavy Metals from Contaminated Dredged Material Placed in Flooded and Upland Disposal Environments. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

A solid-phase plant bioassay was used in an attempt to verify previous dredged material results and to develop a procedure that could indicate phytotoxicity and bioaccumulation of heavy metals in contaminated dredged material. Sediments known to be highly contaminated with one or more contaminants were collected from five freshwater locations in the Great Lakes and five saltwater locations in the U.S. The plant species used as indicators were _Cyperus esculentus_ in the freshwater sediment tests and _Spartina alterniflora_ and _Distichlis spicata_ in the saltwater sediment tests. The bioassays indicated that greater uptake of Cd and Zn occurred from dredged freshwater sediments in the upland disposal environment than from the flooded environment. The reverse was true for As, with an increase in bioaccumulation and phytotoxicity observed in the flooded environment. Factors influencing the availability and plant uptake of the heavy metals include sediment redox potential, organic matter content, total sulfur content, and pH. (WR)

514. Lee, C., R. Hoeppel, G. Hunt, and C. Carlson. 1967. Feasibility of the Functional Use of Vegetation to Filter, Dewater and Remove Contaminants from Dredged Material. Tech. Rept. D-76-4. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

515. Lee, C.R., R.M. Smart, T.C. Sturgis, R.N. Gordon, Sr., and M.C. Landin. 1978. Prediction of Heavy Metal Uptake by Marsh Plants Based on Chemical Extraction of Heavy Metals from Dredged Material. Tech. Rept. D-78-6. U.S. Army Corps of Engineers Waterways Experiment Station. Vicksburg, MS. 107 pp.

Marsh plant species studied included *Spartina alterniflora*, *Spartina patens*, and *Distichlis spicata*. Results indicated that most marsh plants colonizing dredged material disposal sites sampled in this study contained relatively low concentrations of Zn, Cu, Cd, Pb, Cr, Ni, and Hg. These concentrations were very similar to those reported for natural coastal marshes. There were a few locations, however, in which the concentrations of Zn, Cu, Cd, and Pb in the marsh plants were an order of magnitude greater than the concentrations measured in the majority of marsh plants. The occurrence of these elevated concentrations of heavy metals emphasizes the need for a method to predict heavy metal availability from dredged material to plants. (AA)

516. Lee, C.R., T.C. Sturgis, and M.C. Landin. 1976. A Hydroponic Study of Heavy Metal Uptake by Selected Marsh Plant Species. Tech. Rept. D-76-5. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Eight species of marsh plants were grown in chemically controlled hydroponic solutions containing three concentrations of heavy metals to evaluate the ability of each plant species to take up and accumulate heavy metals. The marsh plants were *Cyperus esculentus*, *Scirpus validus*, *Spartina patens*, *Scirpus robustus*, *Distichlis spicata*, *Triglochin maritima*, *Spartina alterniflora*, and *Spartina foliosa*. The heavy metals studied were Zn, Cd, Ni, Pb, and Cr, at concentrations of 0.0, 0.5, and 1.0 ppm. Marsh plants were exposed to heavy metals for six weeks and harvested. Plants were separated into tops, lower stems, rhizomes, tubers, and roots and analyzed for heavy metals to locate plant parts where heavy metals may accumulate.

Exposure to heavy metals adversely affected the growth of *S. validus*, *S. patens*, *D. spicata*, and *S. alterniflora* more than the other plant species evaluated. The species that appeared to have more potential in taking up Zn, Cd, and Ni were *C. esculentus*, *S. patens*, *D. spicata*, and to some extent *S. alterniflora*. Pb and Cr accumulated in the roots of all species with very little translocation into plant tops. Phosphorus and iron content in the roots apopeared to be a major factor in determining the ability of a marsh plant to translocate heavy metals from the roots into other plant parts. (AA)

517. Lee, G.F., E. Bentley, and R. Admundson. 1969. Effect of Marshes on Water Quality. Water Chemistry Laboratory, Madison, WI. 25 pp.

518. Lee, G.F., E. Bentley, and R. Admundson. 1975. Effects of Marshes on Water Quality. pp. 105-127. *In*: A.D. Hasler (ed.), Coupling of Land

and Water Systems. Ecological Studies, Vol. 10. Springer-Verlag, New York, NY.

Four marsh areas located near Madison, Wisconsin, were studied for several years to determine the effects of these wetlands on water quality. Productivity, chemical composition, and nutrient transport from the marshes are described based on data from the sites. It was determined that marshes have both beneficial and detrimental effects on water quality, and that the beneficial effects outweigh the detrimental effects. (EP)

519. Lee, G.F., and R.A. Jones. 1980. An Approach for the Evaluation of Efficacy of Wetlands-based Phosphorus Control Programmes for Eutrophication Related Water Quality Improvement in Downstream Water Bodies. Water, Air, and Soil Pollution 14:359-378.

It has been suggested that re-creation of the marshes that used to exist in the Okeechobee Lake, Florida, watershed is the key to the prevention of further eutrophication of this lake. The need for information on the factors controlling algae and other aquatic growth is stated, and information available on the subject is reviewed. The cycling of the controlling element(s) through restored wetlands must also be considered, and whether a Florida wetland is a significant nutrient trap. The possibility of developing a sufficient acreage of wetlands to maintain and, where possible, improve water quality in Lake Okeechobee is discussed. It is concluded that the proposed wetlands may have limited impact on eutrophication-related water quality of the lake. (AL)

520. Lee, K.W., R.J. Natuk, R.L. Simpson, and D.F. Whigham. 1977. Effects of Sewage on Soil Algae of a Freshwater Tidal Marsh. J. of Phycology Vol. 13 (supplement). 39 pp.

521. Leendertse, J.J. 1970. Environmental Simulation as a Tool in a Marine Waste Disposal Study of Jamaica Bay. Rept. No. P-4163. Rand Corp. Santa Monica, CA. 11 pp.

The study of technical solutions to the problem of managing fluid waste discharges in an estuary involves complicated relationships, such as those between the waste load, the location of discharges, the degree of treatment, the geometry of the estuary, the flow in the estuary, and the temperature. Models can be built to predict the probable consequences of each of the alternative solutions chosen. Using the predictions obtained from these models and whatever other information or insight is relevant, alternatives can be compared and conclusions drawn concerning the most desirable course of action. Such a model for well-mixed estuaries and coastal seas is presented and described. (NT)

522. Lefor, M.W., W.C. Kennard, and T.B. Helfgott (eds.). 1976. Proceedings: Third Wetlands Conference. The University of Connecticut Institute of Water Resources. Report No. 26. August 1976.

The work upon which this publication is based was supported in part by funds provided by the United States Department of the Interior, as authorized under the Water Resources Research Act of 1964, Public Law 88-379.

523. LeFurgey, A., and J.St. Jean, Jr. 1976. Foraminifera in Brackish-Water Ponds Designed for Waste Control and Aquaculture Studies in North Carolina. Journal of Foraminiferal Research. 6(4):274-294.

Effluent may not itself be lethal to foraminifera or deleterious to sedimentary environments but effluent in experimental ponds does not favor foraminifera success. This study determines how sewage effluent affects foraminifera species composition and diversity, standing crops, and seasonal and aeral distribution in six artificial ponds on Calico Creek and Bogue Sound, North Carolina. Each 0.1 acre pond with maximum depth less than one m, was constructed and began operation in late 1968; monthly sampling was initiated in fall 1970. Bogue Sound ponds simulate conditions of a well-flushed shallow marine lagoon typical of U.S. mid-Atlantic coast. Calico Creek ponds simulate a shallow marine marsh estuary polluted by secondary effluent discharged from a sewage treatment plant. Elphidium clavatum is the most common species in both effluent and control ponds. Species diversity is 20% higher and average living-foraminifera numbers are five times greater than effluent ponds. Standing crops in effluent ponds average 4.5 living specimens cc, in control ponds 23.7 living specimens cc. Estimated productivity is trebled in control ponds. Microenvironmental differences in oxygen, pH, and food supply make foraminiferal distribution erratic. Moderate summer phytoplankton blooms occur in control ponds. In effluent ponds, dense winter phytoplankton blooms and concurrently low light levels, devastate original foraminifera populations, creating fluctuating foraminifera ecological significance.

524. Leonard, R.A., Bailey, and Swank, R.R., Jr. 1976. Transport, Detoxification, Fate and Effects of Pesticides in Soil and Water Environments, pp. 48-78. In: Land Application of Waste Materials, Soil Conservation Society of America, Ankeny, IA.

525. Lewis, B.G., P.C. Chee, R.M. Goldstein, F.C. Kornegay, D.L. Mabes, L.F. Soholt, and W.S. Vinikour. 1978. A Biologist's Manual for the Evaluation of Impacts of Coal-Fired Power Plants on Fish, Wildlife, and Their Habitats. U.S. Fish and Wildlife Service. FWS/OBS-78/75. 206 pp.

526. Lewis, J.C., and E.W. Bunce (eds.). 1980. Rehabilitation and Creation of Selected Coastal Habitats: Proceedings of a Workshop, U.S. Fish and Wildlife Service. FWS/OBS-80/27. 162 pp.

527. Lewis, S.J. 1977. Avian Communities and Habitats on Natural and Wastewater Irrigated Vegetation. Master's Thesis. Pennsylvania State University, University Park.

528. Lewis, W.M., and M. Bender. 1961. Effect of a Cover of Duckweeds and the Alga Pithophora Upon Dissolved Oxygen and Free Carbon Dioxide of Small Ponds. Ecology 42:602-603.

The investigation of ponds which had a cover of duckweeds revealed that oxygen was very low and carbon dioxide abnormally high. The observations given indicate that a covering of duckweeds and to a lesser extent a covering of Pithophora can reduce the dissolved oxygen of water to a critical level for fishes. There is also an increase in free carbon dioxide. A comparison between ponds with some cover and a pond without cover demonstrates a marked difference in these two variables.

Although actual fish mortality was observed only once, (Pond 1, 1959) repopulation of Pond 1 by flooding occurred in the fall of 1959 and at the time of the August 1960 observations, the fishes were gasping at the surface.

529. Lin, S.Y. 1974. The Dialectics of a Proposal on Biological Control of Eutrophication in Sewage Lagoons. In: Proc. Conf. on Wastewater Use in the Production of Food and Fiber. U.S. Environmental Protection Agency. Ada, OK.

530. Linde, A.F. 1969. Techniques for Wetland Management. Wisconsin Department of Natural Resources Research Rept. 45. Madison, WI. 155 pp.

531. Linde, A.F., T. Janisch, and D. Smith. 1976. Cattail - The Significance of Its Growth, Phenology, and Carbohydrate Storage to Its Control and Management. Tech. Bull. No. 94. Wisconsin Department of Natural Resources. Madison, WI. 27 pp.

532. Lindsley, D., T. Schuck, and F. Stearns. 1976. Productivity and Nutrient Content of Emergent Macrophytes in Two Wisconsin Marshes, pp. 53-76. In: D.L. Tilton, R.H. Kadlec, and C.J. Richardson (eds.), Proceedings of a Symposium on Freshwater Wetlands and Sewage Effluent Disposal, Univ. of Michigan, Ann Arbor.

This study took place at McNaughton Marsh, a relatively infertile marsh on the Wisconsin River in north-central Wisconsin. The purpose was to determine if aquatic emergent macrophytes influenced the level of available soil nutrients and consequently water quality. Data from this infertile marsh is compared to data from Theresa Marsh, a fertile marsh. Conclusions are that levels of nutrients in the sandy substrate appear to be controlled to a great extent by vegetation. McNaughton marsh appears to function in a similar manner to Theresa marsh with the major difference being the quantity of nutrients involved. Authors suggest that sandy marshes, such as McNaughton, whose soils do not bind nutrients appreciably offer high promise for wastewater treatment. (WE)

533. Lindsley, D., T. Schuck, and F. Stearns. 1977. Primary Productivity and Mineral Regimes in a Northern Wisconsin Marsh, pp. 38-52. *In*: C.B. DeWitt and E. Soloway (eds.), Wetlands Ecology, Values, and Impacts. Proceedings of the Waubesa Conference on Wetlands held 2-5 June 1977. Institute for Environmental Studies, University of Wisconsin, Madison.

McNaughton Marsh, located on the Wisconsin River in north central Wisconsin, is underlain by sands of the Vilas/Crivitz series. During the 1974 growing season primary production of five species of emergent aquatics was determined monthly. Net primary production was found to approximate values reported from much more eutrophic sites elsewhere in North America. Daily productivity above-ground, from the beginning of growth to the time of peak biomass, was as follows: *Sagittaria latifolia* 4.39g/m^2, *Eleocharis palustris* 4.32 g/m^2, *Juncus effusus* 10.3 g/m^2, *Sparganium eurycarpum* 8.8 g/m^2 and *Scirpus validus* 6.3 g/m^2. Mineral nutrient concentrations in McNaughton Marsh plants are comparable to those reported elsewhere, despite the low levels of available minerals in these sandy soils. The nature of the substrate is important in nutrient uptake. Plants growing in McNaughton Marsh appear to "skim off" nutrients from the substrate as rapidly as they are received from river flow and runoff. The degree to which the river nutrient load can be increased without altering the functioning of the marsh system must be resolved by further research. (AA)

534. Lion, L.W. 1980. Cadmium, Copper, and Lead in Estuarine Salt Marsh Microlayers: Accumulation, Speciation, and Transport. Ph.D. Diss. Stanford, Univ., CA. 386 pp.

535. Lisiecki, J.B., and C.D. McNabb. 1975. Dynamics of Hazardous Elements in Wastewater Ponds. Project Completion Report. Office of Water Research and Technology. Washington, DC. 101 pp. (NTIS PB-248 404/GST)

A detailed record was developed of temperature, light, dissolved oxygen, Eh, pH, and sediment characteristics for a municipal waste stabilization pond in Michigan in which the dynamics of Cu and Cd were studied over the growing season. The submersed vascular plants, *Ceratophyllum demersum*, and *Potomogeton foliosus*, and the epineustic *Lemma minor* formed the principal plant population in the pond. Their degree of participation in the budgets of the metals is described. Budgets for total Cu and total Cd were developed for the pond at two or three week intervals from May through September. For the period of study, the plants had a net loss equivalent to 2% of the Cu influent to the pond. There was a net removal of Cd by the pond for intervals from the start of the study to mid-August.

The aquatic plant community showed a net gain in Cd until mid-August, and a net loss with senescence thereafter. The zooplankton and benthic macroinvertebrates of the pond showed net gains and losses that were a very small fraction of the total budgets of the elements. (NT)

536. Lohman, L.C. 1979. An Overview of the Legal, Political, and Social Implications of Wastewater, pp. 459-474. In: R.K. Bastian and S.C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA-430/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Construction Grants Program. Washington, DC.

One of the ways to deal with the legal and political conflicts which could face a wastewater aquaculture proposal would be the establishment of a lead agency to coordinate planning, public information, and legal requirements. Such an agency could address the specific concerns of involved federal and state agencies from a single information source.

Although the national water policy represents a call for innovative methods of water use and treatment, the only real incentive, at present, is the lower construction and operating costs of a wastewater aquaculture facility. These savings could be offset by discharge restrictions, extra testing requirements, or limitations on by-product use. Until the incentive to innovate is clear, outweighing extra demands for educational and environmental safeguards, wastewater aquaculture will not receive wide consideration.

Many of the social and political implications of such a project can be addressed through a properly designed citizen participation program. The public is sometimes ahead of the professionals in willingness to innovate. Only one rule is unchangeable-all official presentations must be completely honest. (AA)

537. Loucks, O., R. Prentki, U. Watson, B. Reynolds, P. Weiler, S. Bartell, and A.B. D'Allessio. 1977. Studies of the Lake Wingra Watershed: An Interim Report. Rept. 78. Center for Biotic Systems, Institute for Environmental Studies, Univ. of Wisconsin, Madison.

538. Lowry, D., and D. Yonika. 1979. Feasibility of Wetland Disposal of Wastewater Treatment Plant Effluent in Massachusetts. In: J.C. Sutherland and R.H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI.

Investigations were carried out to consider the feasibility of utilizing wetland ecosystems for the "polishing" of secondary wastewater treatment plant effluent in Massachusetts. The study involved several distinct but complementary tasks. Task 1 was designed to identify inland and coastal wetlands within Massachusetts which offered potential as sites for acceptance of secondary treated wastewater effluent. Task 2 involved a further focusing of potential study areas down to two wetland areas, one inland and one coastal. Task 3 was designed to complement the evaluation process embodied in Tasks 1 and 2, by monitoring of an actual field situation involving wetland disposal of secondarily treated wastewater effluent. The existing situation at Concord, Massachusetts was selected for this task. At this site secondary treated wastewater effluent is discharged into the "Upper Pool" marsh of the U.S. Fish and Wildlife Service Wildlife Refuge. Water quality improvements through the marsh were noted by annual reductions in BOD (67%), ammonia-N (59%), ortho-P (49%), total P (47%) and nitrate-N (21%). Distinct seasonal variations in marsh renovating capacities were also noted, generally marked by highest removal rates during the spring to mid-growing season, and lowest removal rates (or increase) during the winter.

A recommendation is made to monitor in detail all existing situations in the State where treatment plant effluent is discharged into vegetated wetlands. Multi-variate analysis relating wetland component conditions to water quality results might then provide further elucidation into the feasibility of the concept at specific locations. (AA)

539. Ludwig, R. et al. 1980. The Use and Potential of Aquatic Species for Wastewater Treatment. Appendix E. The Use of Aquatic Systems for Wastewater Treatment: An Assessment. Publication No. 65. California State Water Resources Control Board, Sacramento, CA.

540. Lunz, J.D. 1978a. The Uptake of Toxic Substances by Wetland Soils and Plants. Paper presented at the National Symposium on Wetlands, Lake Buena Vista, FL. November 7-10, 1978.

541. Lunz, J.D. 1978b. Habitat Development Field Investigations, Windmill Point Marsh Development Site, James River, Virginia; Appendix E; Environmental Impact of Marsh Development with Dredged Material: Metals and Chlorinated Hydrocarbon Compounds in Marsh Soils and Vascular Plant Tissues. Technical Report D-77-23. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

542. Lyles, E., M. McCollum, J. Chirieleison, R. Finley, R. Engel-Wilson, and S. Anderson. 1979. A Computerized Ecological Impact Evaluation Method (CEIEM), pp. 365-368. In: G.A. Swanson (ed.), The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats. General Technical Rept. RM-65. Rocky Mountain Forest and Range Experim;lent Station, U.S. Forest Service. Fort Collins, CO.

543. Lynch, J.J. et al. 1947. Effects of Aquatic Weed Infestations on the Fish and Wildlife of the Gulf States, USDI Fish and Wildlife Special Scientific Report, 39, 1947, pp. 1-71.

Lynch evaluated the nature and extent of damage to wildlife and fisheries caused by water hyacinth and alligatorweed, the amount of economic damage caused, and the effect of weed control programs on fisheries and wildlife. Water hyacinth and alligatorweed provide a serious threat because once the species colonize an area they alter the habitat, diminish the value of wildlife, and restrict access of recreationalists. In Louisiana alone the fish and wildlife resource affected annually by the encroachment of these species is estimated to be worth $368,000,000. In all cases, water under mats of hyacinth plants exhibited an oxygen deficit and was unsuitable for fish life. Hyacinth mats also interfere with the normal interchange of gases between the water surface and atmosphere preventing the release of CO_2 and H_2S. It was concluded that a concentrated effort needs to be developed to control the further spread of exotic weed species in the south. (AA)

544. MacGregor, K.A., M.S. Klein, J.S. Bazzolo, and M.E. Delaney. 1980. Municipal Solid Waste Disposal in Estuaries and Coastal Marshlands. U.S. Environmental Protection Agency, Municipal Environmental Research Lab. Cincinnati, OH 183 pp.

This study was accomplished through: questionnaire survey on disposal practices of the coastal states and Puerto Rico that identified the extent of monitoring data available; site visits to state agencies possessing significant monitoring data; and a survey/analysis of State and Federal regulations. In addition, an extensive search of both the formal scientific literature and the "gray" technical report literature was conducted. Recommendations for improvements in regulations, for the mitigation of adverse environmental effects of MSW disposal in the coastal zone and an extensive bibliography are also provided. This study reached the following conclusions:

- MSW disposal sites should be located to prevent leachate migration; operated to minimize leachate production; and monitored and regulated to control the detrimental effects to the environment.
- The impact of municipal solid waste disposal on coastal ecosystems has not been analyzed in depth by eilther the scientific or the regulatory community.
- The only well-documented impact is habitat depletion. There is a high probability that this is also the most serious impact resulting from MSW disposal.
- There are circumstances in which coastal MSW disposal can be used for beneficial purposes, e.g., to provide a substrate for habitat creation. (AA)

545. Maguire, L.A. 1974. A Model of Beaver Population and Feeding Dynamics in a Peatland at Houghton Lake, Michigan. Master's Thesis. Univ. of Michigan, Ann Arbor.

546. Majori, L., and F. Petronio. 1973. Marine Pollution by Metals and Their Accumulation by Biological Indicators (accumulation factor). Rev. Intern. Oceanorg. Med. Tomes XXXI-XXXII.

Mention is first made of the present day toxicological interest taken in the growing environmental pollution by potentially toxic materials. Especially in the marine environment, these dissolved pollutants set serious hygienic problems when the close contact and their affinity, as regards marine organisms, are considered.

The experimental study of the effects of metal pollution simulated in the laboratory, on sensitive biological subjects such as mussels, is useful not only in estimating the negative hygienic consequences on a wider scale, but also for example for purposes of pollution diagnosis by using the mussel as pollution indicator. This investigation can be aided by working out a suitable mathematical model of correlation between pollution and accumulation, for descriptive and predictive purposes.

As regards the experimental procedure, the description of the analytical methods used in our institute for the measurement of the metals in marine water and in biological tissue are described, as well as the methods of maintenance and simulated pollution of the mussels by heavy metals, added as soluble ions.

The results, obtained by using Cd^{++}, CU^{++}, Pb^{++} as soluble pollutants, confirm their accumulation by the mussel and specify the hygienic dangers for the mussel and man, as well as the characteristics of the mussel as indicator of marine pollution. The simplified model of correlation between pollution and accumulation which we use, is very useful to quantify these important aspects. (AA)

547. Mann, R., and R.E. Taylor, Jr. 1981. Growth of the Bay Scallop, *Argopecten irradians*, in a Waste Recycling Aquaculture System. Aquaculture 24(1/2):45-52.

This report presents results of studies of the growth of *Argopecten irradians* both in a pilot scale waste recycling aquaculture system, and in laboratory systems at four temperatures when fed on phytoplankton cultured in sewage-seawater mixtures. Juvenile *A. irradians* were grown successfully on a diet of phytoplankton cultured in sewage-seawater mixtures. *A. irradians* increased from initial live and dry meat weights of 1.15 g and 0.043 g respectively, to terminal values of 9.08 g and 0.599 g, respectively. This corresponds to instantaneous growth rates for live weight and dry meat weight of 0.009 and 0.013, respectively. High mortalities were evident towards the end of the experiment.

548. Mann, R., J.M. Vaughn, E.F. Landry, and R.E. Taylor, Jr. 1979. Uptake of Heavy Metals, Organic Trace Contaminants and Viruses by the Japanese Oyster, *Crassostrea gigas*, Grown in a Waste Recycling Aquaculture System. Tech. Rept. Woods Hole Oceanographic Institution. Wood Holes, MA.

A 24 week study was carried out in which oysters (*C. gigas*) were grown in four regimes: on phytoplankton cultured in a mixture of secondary treated sewage effluent and seawater for a period of 12 weeks followed by a second 12 week period of feeding on phytoplankton cultured in a "clean," organically enriched regime; as above except that the secondary effluent was sand-filtered prior to use; as above except that the effluent was charcoal-filtered prior to use; and using "clean," inorganically enriched phytoplankton food for the 24 week period. At 2 week intervals, oyster populations were removed for assay for trace metals (e.g., Cd, Cr, Cu, Hg, Ni, Pb, and Zn) and organic contaminants (e.g., hydrocarbons and PCBs). No significant accumulation or depuration of any metal or organic contaminant was evident in any of the regimes. In terms of these contaminants all oysters were within acceptable edible standards as set by FDA. A series of experiments carried out to examine the public health implications of enterovirus survival in a mollusk culture system fertilized with secondary treated sewage effluent used MS-2 bacteriophage and vaccine strain poliovirus; apparently depuration could be effected in 20-25 days in *C. gigas* at 15 degrees C. However, this does not mean that such a time span would be adequate for other enteroviruses. (PA)

549. Mann, R., and J.H. Ryther. 1977. Growth of Six Species of Bivalve Molluscs in a Waste Recycling-Aquaculture System. Aquaculture 11(3): 231-246.

Growth of six species of bivalve mollusk (*Crassostrea giges*, *Tapes japonica*, *Mercenaria mercenaria*, *C. virginica*, *mytilus edulis*, and *ostrea edulis*) was compared in a waste recycling-aquaculture system. Tests were conducted at temperatures of 15 and 20 degrees C from November 1975 - May 1976. The animals were fed algae, mostly *Phaeodactylum tricornutum*, enriched with secondary treated sewage effluent. *C. gigas*, *T. japonica*, and *O. Edulis* grew well, but *M. mercenaria*, *C. virginica*, and *M. edulis* exhibited poor growth. The growth of *C. gigas*, *T. japonica*, and *O. edulis* indicates the biological feasibility of producing animal protein through a combined tertiary sewage-treatment-aquaculture system. Although the growth rates presented were not exceptional when compared with those recorded in natural situations, the potential for culture at high densities appears reasonable. (EL)

550. Mariani, G.M. 1979. Development of a Bioassay for the Evaluation of Open Water Disposal of Dredged Material. Ph.D. Univ. of Texas, Dallas. 511 pp.

551. Markarian, R.K., J.E. Balon, and A.C. Robinson. 1977. A Review of Current Interest and Research in Water Hyacinth-Based Wastewater Treatment. Battelle Columbus Labs, Ohio. NTIS No. N77-33683. February, 53 p.

A survey of researchers, literature, and potential users indicates that water hyacinth (*Eichhornia crassipes*) for wastewater treatment can provide a lower-cost method for small cities and towns to meet increasingly stringent effluent requirements. While there have been a few demonstrations of hyacinth systems during the past two years, little design data has been made available. Several full-scale projects are planned for 1977-78. At present there is no source from which to purchase a treatment system or design which has been approved by appropriate regulatory agencies or for which there are demonstrated performance capabilities or cost information. Such a product may be available in three or four years, however, as several suppliers of conventional systems are testing hyacinth designs. Controlled experiments under realistic nutrient loading conditions are needed to develop a satisfactory system. Required data include: (1) optimal physical design (lagoon depth, area, holding time, and harvesting methodology); (2) construction and operating costs; (3) plant-escape prevention techniques; and (4) system performance under various loading conditions and temperature cycles. The best institutional arrangement for such testing would involve a joint effort of an engineering firm, wastewater treatment authority, regulatory agencies and a funding source such as EPA. The use, if any, of harvested plants is not of general concern.

552. Marshall, D.E. 1970. Characteristics of Spartina Marsh Receiving Treated Municipal Sewage Wastes. In: H.T. Odum and A.F. Chestnut (eds.), Studies in Marine Estuarine Ecosystems Developing with Treated Sewage Wastes. Inst. Marine Sci., University of North Carolina. Annual Report 1969-1970.

This study compared an effluent-fertilized and a natural salt marsh through an annual cycle. On the basis of general appearance, the waste receiving marsh in Calico Creek produced a higher biomass of Spartina alternifolia than the natural marsh, thus indicating a beneficial effect of fertilization. The augmented growth of Spartina and its rapid decay were paralleled by a high population of snails, particularly Littorina irrorata. The increased activity of bacteria and rate of decomposition of organic tissues is attributed to the release of nutrients by dead Spartina grass and melampus snails. No significant difference was detected in the subsurface salinity of the two marshes.

553. Marshall, P.E., and N. Pattullo, 1981. Mycorrhizal Occurrence in Willows in a Northern Freshwater Wetland. Plant and Soil 59(3):465-471.

The intensity of mycorrhizal infection in wetland willows growing in central Michigan was not affected by added phosphorus. Two sites were compared, one water-saturated and one drier. P was added at two levels, 20 or 200 kg P per ha, to simulate potential inputs from the disposal of secondary municipal wastewater effluent. Scoring was based on a 0 to 4 scale, 2 and 3 designating the presence of a definite faunal mantle observed by electron microscopy, with 3 having considerable intercellular hyphae and slight epidermal cell elongation. In the wet site, mycorrhizal infection was rated between 1.86 and 3.30, reaching a minimum in August, a a dry month, and a maximum in September. No statistical differences were seen between control, high P, and low P, except in August when the infection was greater than control in the sites receiving P. In the drier site, infection was rated between 1.25 and 3.30, reaching a minimum in August at all sites and a maximum in September at the control site, and a maximum in July in the low and high sites. Low and high P sites had more infection than the controls in July and August, and less in September.

554. Maryland Water Resources Research Center. 1974. Program Activities. Water Resources Research Center. Univ. of Maryland. (NTIS Rept. No. PB-239686).

Research and other program activities under way at the Maryland Water Resources Research Center during FY74 are described, and current and anticipated water problems are identified. The Center's largest project pertains to the potential impact on soils, crops, and other vegetation of emissions of a large, natural draft cooling tower that used brackish water. Other problems being studied include treatment and disposal of farm wastes, urban storm runoff, chlorinated sewage effluents, heavy metals and minerals in Chesapeake Bay sediments, water pollution effects on aquatic life, and contributions of tidal marshlands to food chains in estuaries. (EL)

555. Massachusetts Inst. of Tech. 1977. Electron Irradiation, Sewage Sludge, and Aquaculture. MIT/Marine Industry Collegium Opportunity Brief No. 6. Sea Grant Rept. No. 77-14. Massachusetts Inst. of Tech. Cambridge, MA. 31 pp.

The current state of electron irradiation as a sludge sterilization method is reviewed. The costs with existing methods are compared and some economic projections about the production and sale of sludge as fertilizer are made. Given that the irradiation treatment of sewage sludge produces a nutrient-rich, sterile medium for the culture of microorganisms, a controlled ecosystem could be designed using this nutrient energy base upon which to structure a food web capable of supporting the commercial production of marketable human or animal foods. Such a contrived ecosystem might be managed intensively to achieve high efficiency of production of desired high-value aquatic species. Alternatively, extensive culture systems based on irradiated sludge might be managed to produce large quantities of animal feed composed essentially of algal or fungal single-cell proteins. (NT)

556. Mattson, C.P. et al. 1975. Nitrogen Import and Uptake Measured on Marshes of the Hackensack River in New Jersey. Paper Presented at 38th Ann. Meeting Amer. Soc. Limnol. Oceanogr., Halifax, Nova Scotia. 1975.

557. Mayes, R.A., McIntosh, and V.L. Anderson. 1977. Uptake of Cadmium and Lead by a Rooted Aquatic Macrophyte (Elodea canadensis). Ecol. 58: 1176-1180.

The role of roots in the uptake of nonessential trace metals by aquatic macrophytes was investigated using Elodea canadensis. Plants were grown in 2 lakes in which metal concentrations in the water differed. Specimens in each lake were anchored in either control sediment or in sediment contaminated with Cd and Pb.

Plants grown in the same water but in sediment from different sources had significantly different concentrations of the 2 metals. Elodea samples rooted in sediments from the same source but grown in water with different levels of metals also accumulated significantly different amounts of Cd and Pb. Thus the importance of both sediment and the surrounding water as sources of metals for aquatic plants was demonstrated. Samples grown in water and sediment containing low levels of metals had minimal concentrations of 0.32 microgram Cd/g and 5.2 microgram Pb/g, while plants grown in metal-contaminated water and sediment accumulated up to 32.33 ug Cd/g and 1609 microgram Pb/g. (AA)

558. Maystrenko, Yu. G., A.I. Densiova, V.M. Bagnyuk, and Zh. M. Aryamova. 1969. The Role of Higher Aquatic Plants in the Accumulation of Organic and Biogenic Substances in Water Bodies. Hydrobiological Journal 5(6):10-31.

559. McCaffrey, R.J. 1977. A Record of the Accumulation of Sediment and Trace Metals in a Connecticut Salt Marsh. New Haven Ct. Yale University, Ph.D. Dissertation, 156 p.

560. McCalley, D.V., M. Cooke, and G. Nickless. 1980. Coprostanol in Severn Estuary Sediments. B. Env. Contam. and Tox. 25(3):374-382.

Occurrence of the fecal pollutant coprostanol in the Severn, U.K., estuary was measured. The Severn estuary, which receives sewage outfalls, is used as a public bathing area. Degradation rates of coprostanol in estuarine environments is unknown. However, coprostanol concentrations in Severn water averaged only 0.1-0.3 ppb. (EL)

561. McCool, M.M. 1921. Peat and Muck Soils, Fixation of Fertilizers. Mich. Quart. Bull. 3:126-127.

562. McCormick, J. 1970. The Natural Features of Tinicum Marsh, with Particular Emphasis on the Vegetation, pp. 1-104. In: J. McCormick, R.R. Grant, Jr., R. Patric. Two studies of Tinicum Marsh, Delaware and Philadelphia Counties, PA. The Conservation Foundation, Washington. 123 pp.

563. McCormick, J., R.R. Grant, and R. Patrick (eds.). 1970. Two Studies of Tinicum Marsh, Delaware and Philadelphia Counties, PA. The Conservation Foundation. Washington, DC.

Extensive study on the natural features and purification capability of Tinicum Marsh in Pennsylvania, illustrated that "marshlands play an important role in reducing the nutrient load in water and in increasing the oxygen content." This marsh, however, had "been severely injured by the organic pollution."

564. McDonald M.G., and W.B. Fleck. 1978. Model Analysis of the Impact on Ground-Water Conditions of the Muskegon County Wastewater Disposal System, Michigan, U.S. Department of the Interior, Geographical Survey.

565. McDonald, R.C. and B.C. Wolverton. 1979. Comparative Study of Wastewater Lagoon with and without Water Hyacinth. Econ. Bot. 34(2):101-110.

A three year study was conducted on an existing, one cell, facultative sewage lagoon having a total surface area of 3.6 hectares and receiving a BOD_5 loading rate of 44 kg/ha/da (40 lbs/ac/da). The comparative experimental periods ran from July through November for three consecutive years. During the first period, water hyacinths completely covered the lagoon. The water hyacinth coverage was reduced to 33% of the total surface area the second year. The lagoon, free of all vascular aquatic plants the third year, was monitored for comparative purposes. The most significant improvement overall in the effluent quality occurred when water hyacinths covered the entire lagoon. During this period the effluent BOD_5 and TSS were 23 and 6 mg/l, respectively. Without water hyacinths, the effluent BOD_5 and TSS were 52 and 77 mg/l, respectively. The effluent total organic carbon concentration with water hyacinths averaged 40 mg/l and without water hyacinths, 72 mg/l. A complete discussion of the results from this three year study is presented in this paper along with any associated problems that were observed when water hyacinths were introduced into the lagoon and altered its behavior from that of a normal facultative lagoon. (AA)

566. McGarry et al. 1974. Wastewater Reclamation Under Tropical Conditions. Process. Biochem. 9(7).

Under tropical conditions, nitrogen can be removed from wastewater by growing algae. Processes pertaining to wastewater pretreatment, algal harvest by flotation, chlorination of the final effluent, and removal of low-level organics by semi-rapid filtration are described and compared to adsorption by activated carbon produced from locally available waste products.

567. McGarry, M.G. 1977. Domestic Wastes as an Economic Resource: Biogas and Fish Culture, pp. 347-365. In: Water, Wastes, and Health in Hot Climates. John Wiley and Sons, New York.

Methane produced through fermentation of farm and human wastes is assessed as an alternative to increasingly expensive petroleum-based fuels. This fermentation takes place in a "biogas" unit, which accepts waste materials that digest without access to oxygen. The biogas, largely a mixture of methane and carbon dioxide, bubbles out of the liquid, is trapped, and may be used as fuel for household lighting or cooking. The digested mixture or slurry can be used on the land as a soil conditioner and fertilizer. Various biogas plant designs are described, and the advantages of each are assessed. Fish farming, also, is considered as a means of handling waste materials. The wastes are introduced into fish ponds, where they provide the main source of nutrients for bacterial growth. The byproducts from the wastes' bacterial decomposition, such as ammonia and CO_2, are primary nutrients for the algae, which, in turn, are the basic form of food for many of the fish used in pond culture. (EL)

568. McGarry, M.G. 1979. The importance of Waste Re-use, pp. 91-116. In: Proceedings of the ASCE Appropriate Technology in Resource Conservation and Recovery Symposium. Held Oct. 22-26 in Atlanta, GA.

Human wastes are regarded as a valuable resource in China. Their fertilizer components are valued in agriculture and fish farming operations. Current practices employed in China for the reuse of sewage are surveyed. Composting systems include granular composting, thermophilic composting, and composting toilets. Other uses for this waste, such as direct algal harvesting or gas generation, are being researched in developing nations. (EL)

569. McHarg, I.L. 1976. Biological Alternatives to Water Pollution, pp. 7-13. In: J. Tourbier and R.W. Pierson (eds.), Biological Control of Water Pollution. Univ. of Penn. Press.

570. McIntosh, A.W., E.K. Sheppard, R.A. Mayes, G.J. Atchison, and D.W. Nelson. 1978. Some Aspects of Sediment Distribution and Macrophyte Cycling of Heavy Metals in a Contaminated Lake. J. Environ. Qual. 7:301-305.

Distribution and forms of the metals cadmium (Cd) and zinc (Zn) in sediment and the possible significance of a die-off of the aquatic macrophyte Potamogeton crispus in Cd cycling in a metal-contaminated lake were studied. Metal levels in the upper 5 cm of lake sediment ranged from 2.54 ppm Cd and 115 ppm Zn in an uncontaminated area of the lake to 805 ppm Cd and 6,120 ppm Zn near the entrance of a metal-bearing ditch to the lake. Evidence of metal contamination existed at a depth of 30 cm in sediments in contaminated areas of the system. Dominant forms present in the sediment were the carbonate for Cd and carbonate and organic for Zn. Analysis indicated Cd levels as high as 89.6 ppm in P. crispus in the lake with a maximum burden of 1.5 kg Cd held by the lake's P. crispus population. Release of the total amount could raise water concentrations by a maximum of 1 microgram/liter. (AA)

571. McKim, H.L. (Sym. Coor.) 1978. State of Knowledge in Land Treatment of Wastewater. Vol. 1 and Vol. 2. International Symposium 20-25. August

1978. U.S. Army Corps of Engineers. Cold Regions Research and Engineering Lab. Hanover, NH.

The objectives of this Symposium are to summarize the state of knowledge of the physical aspects of the treatment of wastewater by land application and to identify the suitable approaches for the design of such land treatment systems. The topics to be included are: site selection considerations, case studies of national and international concern, health effects of land treatment systems, pretreatment considerations, uses of wastewaters in agricultural and forest systems, monitoring, modeling and design criteria.

The Symposium Proceedings are published in two volumes. Volume 1 contains the invited papers presented and discussed at the conference. Volume 2 contains shorter papers about on-going research that were selected from the responses received following a call for abstracts.

572. McKinney, R.E. 1976. Functional Characteristics Unique to Ponds. In: E.F. Gloyna, J.F. Malina, Jr., and E.M. Davis (eds.), Ponds as a Wastewater Treatment Alternative. Water Resources Symp. #9. Center for Water Research, College of Engineering, Univ. of Texas, Austin.

573. McLarney, W., and M. Sherman. 1974. Midge Culture at New Alchemy East. Aquaculture and the Fish Farmer 1:10-13.

574. McLeod, K.W., and C. Sherrod, Jr. 1980. Revegetation of Thermally Altered Swamp Forest. Association of Southeastern Biologists Bull. 27(2):49-50.

For 15 years, thermal effluents were introduced into Stell Creek, located on the Savannah River Plant (Georgia). Drastic alteration of the forest occurred during this period with complete loss of the canopy trees. Succession following cessation of thermal effluents in this totally open habitat has been slow and developed more similar to an isolated semiaquatic habitat, rather than a continuous swamp forest. It is important to determine if the establishment requirements for the formerly dominant species are met by the "new" Steel Creek habitat. Studies investigating the germination and seedling growth of Nyssa aquatica, Salix nigra, and Taxodium distichum are discussed. Apparently dispersal mechanisms are responsible for creating a biotic environment which has restricted the establishment of the formerly dominant species, water tupelo and bald cypress. (PA)

575. McMahan, E.A. 1972. Relative Abundance of Three Marsh Floor Organisms in a Sewage Affected Marsh and in a Sewage-free Marsh. J. Elisha Mitchell Sci. Soc. 88(2):61-65

Three marsh-floor dwellers were considered as possible biological indicators of pollution in marine habitats after sampling a spartina marsh exposed to treated sewage wastes and a similar but nonpolluted marsh. Systematic sampling of the marsh surface and the upper 2 cm of substrate was carried out in both marshes to compare population densities of the amphipod, *Talorchestia longicornis*, the collembolan *Sminthurides rubroniveus* var. *levanderi* and the tubificid *Monopylephorus rubroniveus*. The amphipods and collembolans were sampled with a shop vacuum cleaner with an extension tube plugged into a portable generator. Worm samples were taken by pusing a plastic jar, open and down, into the mud to about 2 cm depth. A small plastic spade was used to undercut the jar, trapping the substrate inside. Significantly more collembolans were captured in the sewage-free marsh, and significantly more amphipods and tubificids were captured in the polluted marsh. Presence of amphipods, tubificids, and collembolans in both polluted and sewage-free marshes complicates their use as biological indicators. More studies, involving relative densities of all substrate inhabitants seem indicated. Some other factor of factors--such as sediment size, *Spartina* density, current patterns, or predator pressure--are also considered.

576. McMahan, E.A., and L. Davis. 1978. Density and Diversity of Microarthropods in Wastewater Treated and Untreated Cypress Domes, pp. 429-462. *In*: H.T. Odum and K.C. Ewel (eds.), Cypress Wetlands for Water Management, Recycling and Conservation. Fourth Annual Report. Univ. of Florida, Gainesville.

577. McMahan, E.A., R.L. Knight, and A.R. Camp. 1972. A Comparison of Microarthropod Populations in Sewage-exposed and Sewage-free *Spartina* Salt Marshes. Environmental Entomology 1:244-252.

An investigation of effects of sewage effluents on populations of microarthropods living in *Spartina* marshes was carried out in the spring and summer of 1970. Using primarily a vacuum collecting technique, comparisons of dominant forms, population densities, and species diversities were made between populations inhabiting marsh grass exposed to flooding by treated sewage wastes and those in nonpolluted areas. Only in the case of spiders and amphipods were significant differences found, with density in both cases being greater in the polluted marsh. Species diversity wasd relatively high, especially for populations from *Spartina* growing within margins of artificial ponds, some of which were also exposed to treated sewage wastes.

578. McNabb, C.D. 1976. The potential of Submersed Vascular Plants for Reclamation of Wastewater in Temperate Zone Ponds. *In*: J. Tourbier and R.W. Pearson (eds.), Biological Control of Water Pollution. The University Press, Philadelphia, PA.

The productivity of submersed vascular plants in a series of wastewater treatment ponds was assessed. In the temperate climate of Michigan, submersed plants demonstrated a doubling time of 11 days during the summer (>10°C) until light became a limiting factor due to dense algal blooms. The submersed vascular species flourished best in an environment where Daphnia magna and D. pulex decreased algal densities through grazing and thus increased light penetration and clarity. Nutrients were accumulated primarily from the water through foliage rather than from the sediments through the roots. Strategies for harvesting submersed aquatic macrophytes for maximum yield are discussed. (AA)

579. McNabb, C.D., Jr., and D.P. Tierney, 1972. Growth and Mineral Accumulation of Submersed Vascular Hydrophytes in Pleioeutrophic Environs, Department of Fisheries and Wildlife, Michigan State University, Technical Report No. 26.

Submersed vascular hydrophytes invade ponds designed for stabilizing municipal waste. The adaptability of several species for vegetative growth in pleioeutrophic environments was compared by measuring growth rates. Coontail has a range of tolerance that includes the extremes in water quality that are observed in wastewater ponds. The tissue concentration of phosphorus in submersed plants tended to increase linearly with concentrations of soluble phosphorus in the ambient water. A similar relationship regarding nitrogen was not found. Heavy metals were not discussed or studied. (AA)

580. McNabb, C.D. Jr., D.P. Tierney, and S.R. Kosek, 1972. The Uptake of Phosphorus by Ceratophyllum demersum Growing in Wastewater. Michigan State Univ., Department of Fisheries and Wildlife, East Lansing. Institute of Water Research Technical Rpt. No. 24. 23p.

The cultivation and harvest of aquatic plants at wastewater treatment sites has long been suggested as a first step in recycling minerals. Potential of an aquatic angiosperm for sequestering harvestable phosphorus during growth in a system of sewage oxidation ponds is evaluated. Experimental plants of Ceratophyllum demersum, a cosmopolitan aquatic angiosperm, were selected from a naturally occurring clone in a pond on the Michigan State University campus. Actively growing tips, 30 cm in length, were transplanted to pots placed on the bottom of the third lagoon in a series receiving raw waste from a city. The plant population approached its stationary phase of growth in 57 days. Its dry weight and growth rate compared favorably with maximum rates reported for other aquatic macrophytes. Following transplant, phosphorus concentration in the tissues doubled. Reflecting environmental differences in the amount of the element available to the plants, the terminal phosphorus concentration in tissue in 1.3% of dry weight is twice the maximum value ordinarily observed in field studies. Results suggest that continued attention be given to development of managed crops of aquatic macrophytes as one component is mineral recycling schemes using wastewater.

581. McNaughton, C.D. 1974. Heavy Metal Tolerance of Typha latifolia without Evolution of Tolerant Races. Ecology 55:1163-1165.

Clones of the broad-leaved cattail (Typha latifolia L.) and soil samples were obtained from near a zinc smelter and from a control location. In the smelter location, soil zinc concentration was 385 times higher, cadmium content 37 times higher, and lead content 16 times higher. No evidence for the evolution of heavy metal tolerance could be detected in 2 X 2 experiments in which genotypes from both locations were grown on both soils. Growth of genotypes from both locations was inhibited on the heavy metal soil, but not to the extent that would be expected from previous studies of heavy metal effects. This is the first case described in which a species has been able to colonize heavy metal soils in the absence of the evolution of tolerant races. (AA)

582. McVea, C., and C.E. Boyd. 1975. Effects of Water Hyacinth Cover on Water Chemistry, Phytoplankton, and Fish in Ponds. J. of Environ. Qual. 4(3):375-378.

Water hyacinth [Eichhornia crassipes (Mort.) Solms] cover of 0, 5, 10, or 25% surface was established in fertilized ponds stocked with the fish, Tilapia aurea (Steindachner), at Auburn, Alabama. Measurements of water chemistry, phytoplankton density, and fish production were made during the 1973 growing season.

Phytoplankton production was less in ponds with 10 and 25% cover by water hyacinth than in ponds with 0 and 5% cover. Competition of water hyacinth with phytoplankton involved shading and removal of phosphorus from the water.

Concentrations of dissolved oxygen were lowest in ponds with 25% cover but oxygen tensions in all ponds were adequate for survival and fish growth. (AA)

583. Meany, R.A., I. Valiela, and J.M. Teal. 1976. Growth, Abundance, and Distribution of Larval Tabanids in Experimentally Fertilized Plots on a Massachusetts Salt Marsh. J. Appl. Ecol. 13(2):323-332.

On the Great Sippewissett Marsh (Tabanus nigrovittatus and Chrysops fuliginosus) comprised approximately 90% of the total larvel tabanid population and were both predominantly found in areas where the short form of Spartina alterniflora was the dominant plant. The other two species are T. lineola and C. atlanticus. The average larval densities for T. nigrovittatus and C. fuliginosus found in the control plots of 1972-3 and the 1974 plots are comparable to the maximum values for T. nigrovittatus obtained elsewhere on the east coast of North America. Larval tabanid populations were drasticallyl reduced in plots treated with a sewage sludge fertilizer but were unaffected by treatments with a phosphate and a urea fertilizer. Analysis of monthly larval size classes for the 1972-3 sampling period indicates that the larval life of T. nigrovittatus probably lasts 2 yrs. The summer growth rate is about 4mm/mo. T. nigrovittatus feeds on most soft-bodied insect larvae found on the marsh and also on the amphipod Orchestia grillus. Larval densities were reduced in laboratory experiments from 80-240/m^2 to 40-120/m^2 through cannibalism, the lower figure approximating the densities of larval tabanids found in the field. (BA)

584. Mechenich, D.J. 1980. Tertiary Wastewater Treatment Using a Natural Peat Bog. Master's Thesis, College of Natural Resources, Univ. of Wisconsin Stevens Point. 136 pp.

Significant reductions in effluent concentrations of chloride (60%), alkalinity (100%), hardness (83%), phosphorus (80%), and total suspended solids (95%), were noted based on differences between the effluent and bog outflow water quality during the effluent discharge period. Effluent pH and conductivity were also significantly reduced, while COD increased 204%.

Chloride tracing revealed that the effluent water primarily moved through the bog in the upper 0.5 meter. Other than chloride and conductivity increases, the most significant water quality changes within the bog appeared to be a drop in COD, BOD, phosphorus, and nitrogen below the established background levels at several well sites, and a reduction in background COD in the bog discharge.

Leaching studies using Drummond peat cores were used to estimate the long-term potential of the bog to remove nutrients by physical-chemical processes. Under the specific experimental conditions, net phosphorus removals up to 0.19 mg P/gram oven dry weight peat were found, which was equivalent to approximately 40 kg P/acre-foot of surface peat soil. Nitrogen and calcium removals of 0.45 and 4.5 mg/gram oven dry weight peat respectively were also found. (AA)

585. Meeks, R.L. 1969. The Effect of Drawdown Date on Wetland Plant Succession. J. Wildl. Manage. 33(4):817-821.

A 7-year study was begun on the Winous Point Shooting club in 1956 to determine the effect of drawdown date on plant succession. An 80-acre marsh was diked into four units, one of which was drained yearly in mid-March, one in mid-April, one in mid-May, and one in mid-June. All the units were reflooded during September. Plant succession followed the same general trend on all units, going from semi-aquatic species to predominantly annual weeds. Fewer years were required within early drawdown for annual weeds to replace semi-aquatic species. The May drawdown unit had the best plant associations for wildlife after 7 seasons. Draining during mid-to-late May should allow muskrats (*Ondatra zibethica*) to raise two litters without interruption, and not interfere with duck nesting. (AA)

586. Mees, Q.M., and J.R. Hensley. 1974. Survival of Pathogens in Sewage Stabilization Ponds. Final Rept. Dept. of Civil Engineering, Univ. of Arizona, Tucson. 114 pp.

In semi-arid areas where water supplies are being depleted at alarming rates, re-use of water is of paramount importance. The investigation was initiated in an attempt to determine the survivability of amoebic cysts, intestinal flagellates, and ova of helminths at various phases of the stabilization process. Only those organisms pathogenic to man were to be investigated. (NT)

587. Meo, M., J.W. Day, Jr., and T.B. Ford. 1979. Land Treatment of Fish Processing Wastes on Dredge Spoil Sites: Comparative Cost Evaluations. Coastal Zone Management Journal 3(3):307-318.

588. Merezhko, A.I. 1973. Role of Higher Aquatic Plants in the Self-purification of Lakes and Streams. Hydrobiol. J. 9:103-109.

589. Merritt, R.W. 1978. Insect Pest Problems Associated with Wastewater Oxidation Lakes in Michigan. Project Completion Rept. to Office of Water Research and Technology. Dept. of Entomology. Michigan State Univ. East Lansing, MI. 47 pp.

The distribution and abundance of larval Chironomidae were investigated in the first and last lakes of a 4 lake sewage oxidation system. Chiromid species composition and adult seasonal occurrence were examined and the potential of species to become pests of man was evaluated. A stratified random sampling program was employed to quantitatively sample larvae in Lakes 1 and 4. Each lake was stratified by depth, distance from the influent site, and wind. Samples were taken during the summer and early fall of 1976 and during late spring and early summer 1977. Chironomidae was the dominant subfamily in both lakes initially; the Orthocladiinae gradually becoming dominant in Lake 4 by early summer 1977. The patterns of larval distribution and abundance in Lakes 1 and 4 indicate that the Chironidae actively responded to differences in oxygen and nutrient availability in the sediments by migrating to areas offering favorable conditions. Oxygen appeared to be the limiting factor in Lake 1, nitrogen and phosphorus in Lake 4. (NT)

590. Merrell, J.C., Jr., W.F. Jopling, R.F. Bott, A. Katko, and H.E. Pintler. 1967. Santee Recreation Project, Santee, California. Final Rept. to Federal Water Pollution Control Administration, Cincinnati, OH. 174 pp.

The report presents the results of a study of the Santee, California recreational lakes, which were deliberately planned to utilize the community's reclaimed sewage effluent. By the summer of 1965, a special basin adjacent to one of the lakes was supplied with reclaimed water and used for swimming. This was found possible after progressive use of the lakes for boating and then for fishing. No health hazards have been demonstrated by the viral or other findings. (NT)

591. Metcalf, T.G. 1975. Human Enteric Viruses in a Waste Recycling Aquaculture System. NTIS No. PB 245 909 Final Report. Nat. Sci. Found. 32 pp.

Potential public health hazards from the use of the aquaculture waste recycling system were evaluated. The treatment system consisted of algal ponds in which secondary non-chlorinated sewage was mixed with seawater, and raceways stocked with shellfish. Test viruses were Poliovirus II, Echovirus 5, Coxackievirus B-3, Reovirus 1, and type 5 Adenovirus. Results of the two-year study indicated that the system is unacceptable, if a virus-free effluent is desired, without a second virus inactivating proceses. If virus-free shellfish were to be the parameter of public health acceptance, the full-grown shellfish could be depurated to remove viruses or the sewage effluent could be treated to remove viruses. The system was judged unsafe for use as a means of providing a growth medium for commercially valuable marine life. Further research was recommended.

592. Mhatre, G.N., S.B. Chaphekar, I.V. Ramani Rao, M.R. Patil, and B.C. Haldar. 1980. Effect of Industrial Pollution on the Kalu River Ecosystem. Environmental Pollution; Series A: Ecological and Biological 23(1):67-78.

Vegetation stands above and below industrial discharge points in the Kalu River (India) were studied for relative frequency, relative density, and relative dominance of the component species. Samples of water, sediment, vegetation, and industrial effluents were examined for Cu, Cd, Pb, and Hg by AAS. Aquatic life was severely affected at Ambivali due to toxic discharges from local mills. Although the water quality was not satisfactory at either Ambivali or Titwala, it was much worse at Ambivali. Sediments along the intertidal banks of the river at both locations showed high concentrations of metals. The diversity of plants in the intertidal region at Ambivali was low compared to that at Titwali; 10 species were found at Ambivali, while 20 were present at Titwali. The plant community along the riverbank at Ambivali was dominated by only two species, Cynodon dactylon and Pycreus macrostachyos, which showed high Importance Value Indexes. However, they showed no similar dominance values at Titwali with higher floristic diversity. Replacement of a diverse vegetation by a few tolerant species with a tendency to accumulate toxic metals opens up an interesting field of dynamics of plant populations facing severe pollution stress. (PA)

593. Mickle, A.M., and R.G. Wetzel. 1979. Effectiveness of Submersed Angiosperm-epiphyte Complexes on Exchange of Nutrients and Organic Carbon in Littoral Systems. III. Refractory Organic Carbon. Aquatic Botany 6(4):339-355.

594. Middlebrooks, E.J. 1980. Aquatic Plant Processes Assessment, pp. 43-62. In: S.C. Reed and R.K. Bastian (eds.), Aquaculture Systems for Wastewater Treatment: An Engineering Assessment. EPA-430/9-80-007. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, D.C.

The most common water hyacinth wastewater treatment system incorporates a stabilization pond followed by series-type water hyacinth culturing tanks. The design characteristics of hyacinth systems are discussed in this report, and this paper's conclusions are that:

- Treatment process appears to be applicable in warm temperate and tropical climates, and adequate data appears to be available to assist in the design of a system capable of producing an advanced secondary effluent.
- Water hyacinths thrive in municipal wastewaters and appear to do well in mixtures of municipal and industrial wastewaters.
- A hydraulic loading rate of 2,000 m^4/ha/day to a hyacinth system appears reasonable when treating secondary wastewater treatment plant effluent if nutrient control is not an objective.

595. Mihursky, J.A., 1969. On Using Industrial and Domestic Wastes in Aquaculture. Agricultural Engineering. 50(11):667-689.

Three waste materials have the greatest potential for recycling through aquatic systems into useful nutrients--petroleum wastes, sewage wastes, and waste heat. Protein developed and sold in France is produced by microorganisms growing on waste low-grade petroleum. Large-scale use of microbiologically derived proteins seems possible. Sewage converted to inorganic materials may provide fertilizer for algal production. Waste heat may assist in providing optimal environmental conditions for biological growth at all trophic levels. In various world situations sewage or sewage products are used to stimulate fishery production. Algae grown in mass aided by water from treated sewage and concentrated by evapodrying technique produces food for chickens. Waste heat from steam electric stations is used to raise carp in latitudes farther north than usual and to extend the growing season in some localities. A waste flue gas was used to supply carbon dioxide gas to mass-culture an algal food supply. Wild or natural water is preferable to pond culture. Running water systems permit dense stocking, waste removal and continued dissolved oxygen renewal. Costs of producing fish protein concentrate through aquaculture plus waste utilization will be subsidized by society's need to recycle its waste materials into useful foodstuffs.

596. Miller, H.E. 1973. Production of Fathead Minnows and Muskellunge (Northern and Tiger) in Municipal Wastewater Stabilization Systems. Michigan DNR. Fisheries Div. Grand Rapids, MI.

597. Miner, J.R., J.W. Wooten, and J.D. Dodd. 1971. Water Hyacinths to Further Treat Anaerobic Lagoon Effluent, pp. 170-173. In: Livestock Waste Mangement and Pollution Abatement. American Society of Agricultural Engineers. St. Joseph, MI.

Effluent from an anaerobic lagoon treating liquid swine manure was pumped through a series of four pools, each ten feet in diameter. Water hyacinths were grown on these pools in an effort to provide further treatment. The plants flourished, necessitating weekly harvesting of one-fourth of the growth. During the month of July 1970, nine pounds of ammonia were added to the system in the influent and less than one-fourth pound discharged in the effluent. During this same period, 28 pounds of COD were added and 2.6 pounds discharged. Extrapolating the system to a per acre basis indicates ammonium nitrogen removal to be in excess of 35 pounds per acre per day, COD removal to exceed 100 pounds per acre per day and phosphate removal to exceed 15 pounds per acre per day. Nitrate release was less than 0.3 pounds per acre per day. In one sample weekly harvest (Aug. 14-Aug. 21), 450 plants with a total wet weight of 90 lbs. were removed from two of the ponds having a combined area of approximately 160 sq.ft. This corresponds to an increase of over 17,000 new plants per acre per day and an increase in wet weight of over 2500 pounds per acre per day. At a 4% dry weight conversion factor, this equals 100 pounds of dry weight per acre per day. The system has performed satisfactorily showing potential as a means of removing nutrients from partially treated animal wastes which are not removed by currently used processes.

598. Mitsch, W.J. 1975a. Observation on Utilization of Wetlands Ecosystems for Sewage Treatment, pp. 90-113. In: H.T. Odum, K.C. Ewel, J.W. Ordway, and M.K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

599. Mitsch, W.J. 1975b. Systems Analysis of Nutrient Disposal in Cypress Wetlands and Lake Ecosystems in Florida. Ph.D. Diss., Univ. of Florida, Gainesville. 421 pp.

Models, field measurements, and computer simulations were used to evaluate alternative systems of man's nutrient cycling using a freshwater lake and cypress swamps in Florida. Ecological characteristics, nutrient budgets, organic productivity, energy relations, and interfaces with man's economy were compared between the two systems. The two systems responded similarly to the addition of nutrients through the introduction of plants with low quality structure, intermediate in biomass between phytoplankton of the lake and trees of the dome. Preliminary evaluation of cypress dome, lake and technologically based nutrient disposal alternatives suggest that the cypress system may realize a higher work service per purchased energy invested. (AA)

600. Mitsch, W.J. 1976a. Ecological Engineering Through the Disposal of Wastewater into Cypress Wetlands in Florida. In: Proceedings of the National Conference on Environmental Engineering Research, Development and Design. Univ. of Washington, Seattle.

601. Mitsch, W.J. 1976b. Ecosystem Modelling of Water Hyacinth Management in Lake Alice, Florida. Ecol. Modelling, 1:68-69.

602. Mitsch, W.J. 1977. Water Hyacinth (*Eichhornia crassipes*) Nutrient Uptake and Metabolism in a North Central Florida Marsh. Archiv. fur Hydrobiologie. 81(2):188-210.

Effects of high nutrient loading from secondary sewage effluent on the marshy eastern part of Lake Alice, Gainesville, Florida were studied, with special attention to the disposition of nitrogen and phosphorus, and to the metabolism of water hyacinth (*Eichhornia crassipes*) which dominates the marsh. Construction of an earthen dam in 1948 and addition of the sewage effluent and heated once-through condenser water from a heating plant in 1964 increased the lake's size from four to thirty-three ha. High nutrient levels and water temperatures in the 29-31 range have resulted in gross primary productivity among the highest ever reported--19.3 g C/sq m/day for large hyacinths and 15.6 g C/sq m/day for dwarf hyacinths. Net production efficiencies were about 1.6% of solar insolation for both plants. Uptake of total nitrogen averaged 49% across the marsh. Nitrate showed a seasonal pattern of greater uptake from winter to summer; phosphorus uptake averaged 11% with signs of a net phosphorus export in winter. Rapid nutrient turnover and high water hyacinth metabolism apparently accounts for the low percentage of nitrogen and phosphorus uptake. Seasonal changes in nitrate levels leaving the marsh suggest denitrification is a significant nitrogen sink, and sediments continue to act as an additional nitrogen source to overlying waters. Use of a hyacinth marsh as a natural tertiary treatment system would require much lower nutrient loading rates to be effective.

603. Mitsch, W.J., C.L. Dorge, and J.R. Wiemhoff. 1977. Forested Wetlands for Water Resources Management in Southern Illinois. Research Rept. 132. Water Resources Center, Univ. of Illinois. 275 p.

604. Mitsch, W.J., C.L. Dorge, and J.R. Wiemhoff. 1979. Ecosystem Dynamics and a Phosphorus Budget of an Alluvial Cypress Swamp in Southern Illinois. Ecology 60(6):1116-1124.

Annual patterns in hydrology, phosphorus circulation, and sediment dynamics were studied in a southern Illinois, USA floodplain swamp dominated by bald cypress (*Taxodium distichum*) and swamp tupelo (*Nyssa aquatica*). The study emphasized the swamp's interactions with the adjacent river. For the year, major inputs of water to the swamp were throughfall (74.3 cm) and runoff (69.4 cm) with monir contributions due to groundwater (21.6 cm). Outflows were by evapotranspiration (72.3 cm), surface outflow (56.5 cm), and groundwater (21.0 cm), with the latter two draining primarily to the river. A flood occurred during the study period, passing 1.6 x 10^7 m^3 of river water over the swamp and depositing 0.06 cm of sediments.

An annual phosphorus budget was developed for the swamp from field measurements. The greatest input of phosphorus to the swamp was 3.6 g P

m^2 yr^1 due to deposition of high-phosphorus sediments during the flood. This was 10 times greater than the outflow of phosphorus to the river. 0.34 g P m^2 yr^1, and 26 times greater than the throughfall input of 0.14 g P m^2 yr^1. Total tree uptake from sediments was estimated to be 0.87 g P m^2 yr^1 of which 0.77 g P m^2 yr^1 returns as litterfall to the swamp sediments. Duckweed productivity was estimated to take 3.3 g P m^2 yr^1 from the water column and deposit this in the sediments during die-off.

For the period 1937-1967, cypress growth, based on tree ring analyses, was closely correlated with several measures of flooding frequency and magnitude, all obtained from past river data. Tree ring data prior to 1937 showed poor correlation with flooding, probably because of logging activity. Cypress growth has decreased dramatically in recent years, corresponding to the rise in water level caused by beaver activity. (AA)

605. Mitsch, W.J., M.D. Hutchison, and G.A. Paulson. 1979. The Momence Wetlands of Kankakee River in Illinois - An Assessment of Their Value. A Descriptive and Economic Approach to the Appraisal of Natural Ecosystem Function. State of Illinois, Institute of Natural Resources, Chicago, IL, 55 pp.

606. Mitsch, W.J., and K.C. Ewel. 1979. Comparative Biomass and Growth of Cypress in Florida Wetlands. The Amer. Midl. Nat. 101(2):417-426.

Tree biomass and increase in biomass were determined for cypress (*Taxodium distichum*) in different systems in Florida, USA. Ten trees were harvested to determine biomass regressions. Lowest biomass and tree growth rates were found in cypress-pine associations indicative of low water, in monospecific stands of cypress which are indicative of high water levels, and in a poorly drained cypress dome. Increases in individual tree growth rates were found in cypress-tupelo systems and cypress-hardwood systems. The latter are less dominated by cypress, so individual tree growth is greater (7.7 kg/yr vs. 4.0 kg/yr). Cypress-hardwood associations are generally better drained than cypress-tupelo sysems. Two experimental cypress domes currently receiving treated sewage effluent and groundwater showed high individual tree growth (5.0 and 4.2 kg/yr, respectively), but little difference was noted between the two domes. Tree diameter increase showed normal cypress tree growth to be 1.0-2.0 mm/yr with higher values of 2.8-3.3 in cypress-hardwood associations and the experimental cypress dome. Cypress in the poorly drained dome increased by only 2.0 mm/yr. (BA)

607. Mitsch, W.J., H.T. Odum, and K.C. Ewel. 1976. Ecological Engineering Through the Disposal of Wastewater into Cypress Wetlands in Florida. National Conference on Environmental Engineering Research, Development and Design. Univ. of Washington, Seattle.

1085. Monge, D. 1978.

608. Montroni, R. 1980. The Importance of Riparian Zones to Terrestrial Wildlife; An Annotated Bibliography. U.S. Fish and Wildlife Service. Sacramento, CA. 83 pp.

609. Mood, E.W. 1976. Epidemilogic and Public Health Implications of Wetlands, pp. 116-120. In: M.W. Lefor, W.C. Kennard, and T.B. Helfgott (eds.), Proceedings: Third Wetlands Conference. Rept. No. 26. Institute of Water Resources, Univ. of Connecticut, Storrs.

This paper addresses two major concerns of medical and public health authorities about wetlands: (1) the use of subsurface absorption systems in or immediately adjacent to wetlands as a means of wastewater disposal; and (2) that wetlands provide breeding habitats for mosquitoes which are direct or indirect vectors of human disease (e.g., eastern equine encephalitis). (DM)

610. Moore, J.W. 1979. Diversity and Indicator Species as Measures of Water Pollution in a Subarctic Lake. Hydrobiologia 66:73.

611. Moraine, R. et al. 1979. Algal Single Cell Protein from Wastewater Treatment and Renovation Process. Biotech. and Bioeng., XXI:1191-1207.

612. Moreau, G.D. 1976. Effects of Fertilizers on Aquatic Vegetation. Master's Thesis. Dept. of Wildlife Science, Utah State University, Logan. 40 pp.

613. Morel, F.M.M., and S.L. Schiff. 1980. Geochemistry of Municipal Waste in Coastal Waters. Rept. No. 259. Mass. Inst. of Tech. Cambridge. 205 pp.

614. Mosey, F.E. 1976. Assessment of the Maximum Concentration of Heavy Metals in Crude Sewage Which Will Not Inhibit the Anaerobic Digestion of Sludge. Water Pollultion Control 75:10-20.

615. Motts, W.S. 1972. Environmental Impact of Alternative Waste Disposal Methods. Cooperative Extension Service. Univ. of Mass., Amherst, Mass.

616. Moulton, D.W, W.I. Jensen, and J.B. Low. 1976. Avian Botulism Epizootiology on Sewage Oxidation Ponds in Utah. J. Wildl. Management 40(4):735-742.

In the microenvironment concept of avian botulism epizootiology, it is hypothesized that invertebrate carcasses may serve both as a substrate for toxin production by Clostridium botulinum type C and as a vehicle for toxin transmission to water birds. We field-tested that hypothesis by attempting to induce botulism in wing-clipped mallard ducks (Anas platyrhynchos) on sewage oxidation ponds in Utah. The experimental ponds were inoculated with C. botulinum spores in June 1974. Aquatic insect populations were monitored throughout the summer. Rotenone was used in August to kill insects in two ponds (one served as control), thereby providing potential substrate for clostridial growth and toxin production. Botulism was not detected among the birds even though they routinely ingested invertebrate carcasses. Samples of dead invertebrates contained no botulinum toxin. We concluded that the microenvironment concept, as it now stands, cannot always be a sufficient explanation of how type C botulism epizootics are initated in nature. Other microbes may inhibit the growth of clostridial cells or destroy botulinum toxin. (AA)

617. Mudroch, A. and J.A. Capobianco. 1978. A Preliminary Study on a Natural Marsh Receiving Sewage Treatment Plant Effluent. Canada Centre for Inland Waters, Geology Section, Process Research Division. Burlington, Ontario, Canada. 45 pp.

Long-term effects of poor quality wastewater treatment plant effluent on a natural marsh on the western shore of Lake Ontario, Canada, were studied. The major contributor of N and P to the marsh area was the treatment plant discharge. The effect of the effluent on plant communities, and the availability and cycling of nutrients and heavy metals in the marsh are discussed. Metal concentrations in the water were generally low. Increased concentrations of Pb, Cr, Zn, N, P, and organic C were found in the sediment vertical profile obtained from the marsh area. The submersed aquatic plants collected from the marsh area accumulated larger quantities of Pb, Zn, Cd, and Cr than the same species collected at the station in the pond outside the marsh area. The shoot standing crop of the dominant plant species (Glyceria grandis) was associated with amounts of P, N, and organic C in the sediments. (BA)

618. Mudroch, A., and J.A. Capobianco. 1979. Effects of Treated Effluent on a Natural Marsh. J. Water Poll. Control. Fed. 51(9):2243-2256.

Changes in biomass tissue nutrient levels, and tissues metal levels in emergent marsh vegetation as a function of increasing distance from a sewage discharge were studied at a site in Ontario. All three parameters decreased with increasing distance.

Sediments were indicated as the possible source of heavy metals. Floating and submerged aquatic vascular plants adsorbed greater levels of heavy methods than did emergent plants. (EP)

619. Murnyak, M.O. and D.F. Murnyak. 1981. Aquaculture in Minnesota's Wetlands. pp. 51-58. In: B. Richardson (ed.), Selected Proceedings of the Midwest

Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

The feasibility of raising fish as a source of food in Minnesota farm ponds is the focus of an ongoing research and extension project centered in Wright County, Minnesota. Studies over the past three years have shown the farm ponds larger than 0.1 ac in size, averaging 4' or more in depth, can be used for food fish production on a seasonal or year-round basis. Ideally, areas to be used for fish production should have a reliable source of good quality water, a controllable water level, and allow complete drainage. Lowland areas such as marshes and swamps that have abundant vegetation or are subject to flooding or greatly fluctuating water levels are not recommended for fish farming. The choice of production method and species to culture is determined by the water quality conditions and the suitability of the site for intensive management. Cold water ponds can be used for trout (Salmo spp.) production, where year-round growth is possible if flowing water is available. Warm water ponds can be used for seasonal production of channel catfish (Ictalurus punctatus), bluegill sunfish (Lepomis macrochirus), black crappies (Pomixis nigromaculatus), yellow bullheads (Ictalurus natalis) and largemouth bass (Micropterus salmoides). Standing ponds averaging less than 15' deep are subject to winterkill, and must be completely harvested each year unless aeration is provided. At this time it appears that using farm ponds for fish production in Minnesota is economical for home-use, but not for commercial operations. (AA)

620. Murphy, C.B. 1981. Bioaccumulation and Toxicity of Heavy Metals and Related Trace Elements. J. of Wat. Pollut. Control Fed. 53(6):993-998.

621. Murray, C. 1976. Weeds Hold Promise for Pollution Cleanup. Chemical and Engineering News. 54(12):23-24.

The water hyacinth is being tested as a means of sewage treatment for small towns which cannot afford the capital investment necessary with conventional treatment techniques. The water hyacinth is a vascular plant containing a system of vessels that transport nutrients from the roots through the leaves while absorbing large quantities of nutrients and pollutants found in domestic sewage. The hyacinth also has the ability to concentrate heavy metals and organic substances often present in industrial wastes. National Aeronautics and Space Administration (NASA) officials have been conducting research at Bay St. Louis, Mississippi. In the spring of 1975, three acres of a 40-acre municipal lagoon that receives raw sewage from about 6000 households was planted with water hyacinths. Although three acres was insufficient to clean up the entire lagoon, planting 12 acres of the lagoon with hyacinths in summer of 1976 is expected to produce clean water in the lagoon. Uses for water hyacinths produced are also being explored. In a study at the Mississippi State University Agricultural Experiment Station, hyacinths grown in municipal sewage were dried, ground into meal, and added to cattle feed. The hyacinth meal is high in minerals and protein and comparable to cottonseed meal or soybean meal as a feed supplement. NASA is researching the conversion of water hyacinths into methane by anaerobic fermentation. Residue produced by anaerobic digestion is an efficient fertilizer and soil conditioner.

622. Nathans, M.W. and T.J. Bechtel, 1977. Availability of Sediment-adsorbed Pesticides to Benthic with Particular Emphasis on Deposit-Feeding in Fauna. U.S. Army Corps Tech. Rpt. D-77-34.

623. National Academy of Sciences. 1976. Making Aquatic Weeds Useful: Some Perspectives for Developing Countries. Washington, DC., 174 pp.

Aquatic weeds are becoming a menace at alarming rates in many parts of the world. Several methods for controlling these aquatic macrophytes are presented and discussed in semi-detail, i.e. utilization of herbivorous animals, harvesting techniques, and other uses such as wastewater treatment and aquatic plants for food. Each section includes a bibliography and a listing of research contacts. (AA)

624. National Science Foundation. 1977. Putting Wetlands to Work. (Cypress Domes and Peatlands Offer Ecologically Sound, Energy-Conserving Wastewater Disposal). NSF Mosaic 8(3):25-29.

This article reprint reports on two research projects, conducted in Florida and in Michigan, designed to ascertain the capability of wetlands to absorb partially treated wastewater from municipal facilities. These studies are part of an accumulating body of research that suggests that wetlands are ecological systems that not only can absorb treated effluents while treating them in a natural rather than energy-consuming, artificial way, but can benefit from the fertilization secondarily treated effluents are able to provide. The research suggests that as long as the effort is based on understanding of the wetlands environment, it represents a way that civilized man can return to a symbiotic relationship with an important part of his natural environment. There is substantial opportunity for small communities which occupy a large part of our geography to take advantage of the results of these experiments. (NT)

625. National Science Foundation. 1980. Wetlands. Our Natural Partners in Wastewater Management, 16mm Film in Sound and Color. Directorate for Engineering and Applied Science. Washington, DC.

626. Natter, A.S., and D. Walrath. 1976. Aquaculture - New Broom Cleans Up Wastewater. Water and Wastes Engineering 13(2):38-41.

627. Neary, D.G., G. Schneider, and D.P. White. 1975. Boron Toxicity in Red Pine Following Municipal Wastewater Irrigation. Soil Sci. Soc. of Am. Proc. 39:981-982.

628. Neel, J. K., and G. J. Hopkins. 1956. Experimental Lagooning of Raw Sewage. Sewage and Industrial Wastes 28(11):1326-1356.

The authors outline studies being carried out at several places in U.S.A. on treatment of sewage by aquaculture systems, in which sewage is treated in lagoons. The problems of harvesting phytoplankton are overcome either by culturing filter-feeding shellfish to consume the phytoplankton, or by growing higher aquatic plants such as water hyacinth. Flow diagrams of two proposed systems are included, and factors to be taken into account before such a scheme can be implemented are listed. (AL)

629. Neff, J. W., R. S. Foster, and J. F. Slowey. 1978. Availability of Sediment-Adsorbed Heavy Metals to Benthos with Particular Emphasis on Deposit-Feeding Infauna. Tech. Rept. D-78-42. U.S. Army Corps of Engineers Waterways Experiment Station, Environmental Laboratory. Vicksburg, MS. 311 pp.

Biological laboratory studies were conducted to evaluate the bioavailability of sediment-adsorbed heavy metals to benthic invertebrates. For these studies, five test organisms (*Rangia cuneata*, *Palaemonetes kadiakensis*, *Neanthes arenaceodentata*, and *Tubifex sp.*) were exposed to metal-enriched natural sediments for periods up to six weeks at different salinities. The test sediments came from Texas City and Corpus Christi, Texas, ship channels and Ashtabula, Ohio, harbor. The accumulation of eight heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) by all species was measured.

Statistically significant accumulation of metals from sediment was demonstrated only 36 times (26.5%) out of 136 metal-species-sediment test combinations. Variations in bioaccumulation were observed between species, metals, sediments, and salinity. In these studies, correlation was not observed between accumulation and specific metal forms as determined by selective chemical extraction of test sediments. Bulk metal analyses of the test sediments also did not correlate with metal bioavailability. (AA)

630. Neil, J. H. 1976. The Harvest of Biological Production as a Means of Improving Effluents From Sewage Lagoons. Canada-Ontario Agreement on Great Lakes Water Quality Research Rept. #38.

631. Nelson, S.G., B.D. Smith, and B.R. Best, 1981. Kinetics of Nitrate and Ammonium Uptake by the Tropical Freshwater Macrophyte *Pistia stratiotes* L. Aquaculture, 24 (1/2):11-19.

The kinetics of nitrogen uptake were examined for a common freshwater macrophyte Pistia stratiotes L. Nitrate-nitrogen and ammonium-nitrogen uptake were examined over a wide range of substrate concentrations gather information which would be useful in the design of aquaculture systems for ammonium and nitrate removal. Nitrate uptake rates were higher after 24 hr. of exposure to the nitrate source than immediately after exposure. The rate of uptake of nitrate-nitrogen was greater in the light than in the dark. Nitrate uptake followed a pattern which could be adequately described by the Michaelis-Menten expression. Ammonium nitrogen uptake response to substrate concentration appeared to be linear. Rates of ammonium-nitrogen uptake was similar in the dark and in the light. For any given dissolved nitrogen concentration, the rate of ammonium-nitrogen uptake was greater than the rate of nitrate-nitrogen uptake.

632. Nessel, J. 1978. Distribution and Dynamics of Organic Matter and Phosphorus in a Sewage Enriched Cypress Swamp. Master's Thesis. Department of Environmental Engineering Sciences, Univ. of Florida, Gaines--ville. 150 pp.

633. Nessel, J.K., and S.E. Bailey. 1980. Distribution and Dynamics of Organic Matter and Phosphorus in a Sewage-Enriched Cypress Swamp. In: H.E. Odum and K.C. Ewel (eds.), Cypress Wetlands for Water Management, Recycling and Conservation. Fifth Annual Report to NSF and Rockefeller Foundation, NSF Grant #PFR-7706013, Rockefeller Foundation Grant #RF-76034.

634. Neuhold, J. M. 1971. The Study of the Physical, Chemical, and Biological Nature of Water Quality Under Utah Conditions. Completion Rept. Utah State Univ., Logan, UT. 100 pp.

Addition of domestic sewage effluent into a high mountain valley stream can produce a complexity of effects on receiving waters. Mountain streams are cold waters which have envolved a diverse biological system adapted to cold temperature, clear water and in which sewage effluents can persist for relatively long periods of time. The lower Logan River below the City of Logan is such a stream. It receives domestic effluent from the City of Logan, which at the start of the study went directly, untreated, into the Logan River, and during the course of the study was diverted through an extensive primary-secondary-tertiary treatment lagoon system returning treated water back to the receiving stream. The physical, chemical, and biological qualities of the Logan River were studied before and after treatment. The development of a biological system and its effect on the physical and chemical qualities in the lagoon system, built essentially upon a primordial substrate, were also studied. An annotated bibliography of 250 references on wastewater stabilization ponds is included. Tertiary treatment ponds can be ecologically managed to minimize organic build-up. Design criteria should also be established to maximize retention time to fully utilize the ecosystem developed in the pond. Free-form designs are suggested as a possible means to accomplish this with the added benefit of improving aesthetics of the problem. (NT)

635. Nichols, D. S. 1980a. Developing Environmentally Safe Procedures for Sewage Waste Treatment Using Organic Soils and Peat Materials. Unpublished report. U.S. Forest Service, North Central Forest Experiment Station, Grand Rapids, MN, 54 pp.

636. Nichols, D. S. 1980b. Nutrient Removal from Wastewater by Wetlands. Paper presented at the 6th International Peat Congress, August 17-23, Duluth MN. 23 pp.

Interest in wetland applications as a means of removing N and P from wastewater is rapidly increasing. However, the capacity of wetlands to function in this manner has not been well quantified. This paper briefly reviews the literature on this topic. The retention of inflowing P by wetlands under natural conditions seems to be limited to the relatively small amount that is accumulated as peat is formed from partially decayed vegetation. When P in excess of natural levels is added to a wetland, some is adsorbed by the soil. The efficiency with which wastewater P is removed is highest at low loading rates and decreases rapidly as loading rates increase. Removal of P also declines with time; short-term studies can give misleadingly high estimates of ultimate P removal capacities. The removal of N in excess of the natural rate of accumulation in the peat is apparently by denitrification. As with P, the efficiency of N removal decreases rapidly as loading rates of wastewater N are increased. The rate of denitrification may be limited by the rate of nitrification or NH_4-N, $N0_3$-N, or 0_2 diffusion. From the sparse data available in the literature it is estimated that 1 ha of wetland would be required to remove 75 percent of the P generated by 15 people and 75 percent of the N from 20 people, or 54 percent of the N and P generated by 50 people. Wetland application is feasible only where wetlands are abundant and population densities are low. (AA)

637. Nichols, D.S. [No Date] Capacity of Natural Wetlands to Remove Nutrients from Sewage. U.S. Forest Service, Grand Rapids, MN 24 pp. plus references and illustrations.

The mechanisms by which wetlands remove nutrients were reviewed. A model of the relationships between rates of wastewater application and efficiencies of removal of N and P was developed on the basis of data from nine natural wetlands used for wastewater treatment: six located in the U.S., two located in Canada, and one located in Ireland. It was concluded that natural wetlands can remove nutrients from wastewater effectively, but only if the population density is relatively low and wetlands are relatively abundant. Approximately 1 hectare of wetland was estimated to be required for 50% removal of nitrogen and phosphorus for every 60 people. An extensive (131 references) bibliography is included. (EP)

1086. Nichols, D.S. 1983.

638. Nichols, D.S. and D.H. Boelter. 1982. Treatment of Secondary Sewage Effluent With a Peat-Sand Filter Bed. J. Environ. Qual. 11(1):86-

A peat-sand filter bed was constructed to provide additional treatment of the secondary sewage effluent from a campground located on the shore of North Star Lake, within the Chippewa National Forest in north-central Minnesota. This effluent contained an average of 30.9 mg/liter total nitrogen, 8.63 mg/liter total phosphorus, and 122,000 fecal coliforms/ 100 ml. An average of 6.8 cm/week was applied from late May through early October for 8 years. The peat-sand filter bed accomplished almost complete removal of fecal coliform bacteria and P. About 90% of the waste water N was removed during the 2nd and 3rd years of operation, but this declined to about 50% by the 5th year, due to oxidation of the peat and release of N. The high Fe, Al, and ash content of the peat contributed to the filter's highly efficient removal of P. Microbial immobilization in the peat contributed to N and P removal during the first 2 or 3 years of waste water application. Rough stalked bluegrass (*Poa trivialis L.*) planted on the peat surface of the filter was very important in overall N and P removal. Nutrient uptake by the bluegrass increased each year and accounted for 45% of the P and virtually all of the N removed from the waste water in the 5th year of the study. (AA)

639. Niering, W. A. 1972. The Wetlands. Ecol. Today 2:32-36.

Four major roles of freshwater wetlands are discussed, including: hydrologic, productivity, pollution filtration, and education/recreation. Examples are cited from wetlands throughout the U.S. Includes a separate article on saltwater wetlands. (DM)

640. Niering, W. A. 1973. The Ecological Role of Inland Wetlands, pp. 100-109 and 163-164. *In* T. H. Helfgott, M. W. Lefor, and W. C. Kennard (eds.), Proceedings: First Wetlands Conference. Rept. No. 21. Inst. Water Res., Univ. of Connecticut, Storrs.

Five wetland types -- marsh, wooded swamp, bog, floodplain, and stream belt -- and their associated vegetation are discussed, followed by explanations of the numerous roles of wetlands including: flood control, siltation or sediment trapping, recharging the water table, pollution filtration, oxygen production, productivity, aid in maintenance of a balanced nitrogen cycle, education, and recreation. (DM)

641. Nixon, S. W., and C. A. Oviat. 1973. Analysis of Local Variation in the Standing Crop of *Spartina alterniflora*. Botanica Marina 16:103-109.

Measurements of standing crop biomass and height of the tall form of *Spartina alterniflora* on 12 Rhode Island salt marshes suggests that the nutrients of municipal sewage inputs may increase cordgrass growth. Even with enhanced growth from eutrophication, calculations show that treatment of marsh areas with sewage effluents is not a realistic hope for the recycling of wastes from coastal cities, or for providing low cost tertiary treatment. (WE)

642. Noble, R. 1975. Growing Fish in Sewage. New Scientist 67:259-261.

643. North Atlantic Treaty Organization. 1976. Harvesting Polluted Waters: Waste Heat and Nutrient-Loaded Effluents in Aquaculture. Plenum Press, New York. 335 pp.

This symposium was concerned with the scope for making use of the thermal pollution produced by power stations, and the waste minerals contained in domestic sewage, for the greater production of the primary and intermediate components in the food chain of fresh and salt water fish. Topics discussed covered the selection of sites where thermal "pollution" could be expected to produce beneficial results (e.g., fjords and nearly-closed bays), the idea of constructing "marine greenhouses," the deliberate eutrophication of selected areas with attendant algal proliferation, the development of existing shellfish beds and the introduction of new species to heated areas, and the possibilities of improving the rearing of fish fry for release and cultivation. There is one paper drawing attention to the safeguards that would have to be implemented when using domestic sewage for aquaculture. (AL)

644. Notermans, S., A. H. Havelaar, and J. Schellart. 1980. The Occurrence of *Clostridium botulinum* in Raw-Water Storage Areas and Their Elimination in Water Treatment Plants. Water Research 14(11):1631-1635.

Large scale outbreaks of waterfowl botulism in 1976 in the Netherlands have raised questions about the effectiveness of *Clostridium botulinum* removal by three water treatment plants. The Leiduin, Weesperkarspel and Kralingen treatment plants each receive water from three storage areas where *C. botulinum* was detected in bottom mud samples. The extent of removal of the bacterium by routine treatment operations of the plants was examined, and model experiments were conducted to evaluate the efficiency of slow sand filters in removing Clostridium spores. Samples were taken from coagulation sludge and the upper layers of filters in all three plants and also from the bottom sediments of ozone treatment chambers from the Weesperkarspel plant. The presence of *C. botulinum* was determined by mouse antiserum bioassays. Results of the three year investigations (1977-1979) indicated that slow sand filters were adequate for retaining *C. sporogenes* spores. In two of the plants, the Weesperkarspel and Kralingen plants, *C. botulinum* was found only in the early purification stages. At the Leiduin facility, *C. bacteria* were also detected on the slow sand filters, the last step of purification. The bacterium was detected in only the upper sand layers of this plant, and was never found in the filter water of any of the three treatment facilities. (WR)

645. Nute, J. W. 1975. Mt. View Sanitary District Marsh Enhancement Pilot Program. Progress Rept. No. 1. J. Warren Nute, Inc. San Rafael, CA. 9 pp.

646. Nute, J. W. 1977. Mt. View Sanitary District Marsh Enhancement Pilot Program. Progress Report No. 2. J. Warren Nute, Inc. Civil & Sanitary Engineers, San Rafael, CA.

The data from the pilot marsh operation for the period from January, 1975 to July, 1976 indicate that secondary effluent can be used to create beneficial waterfowl habitat. The pilot marsh areas established by Mt. View Sanitary District receive heavy use by waterflow and other birds. Studies begun in November, 1976 will provide additional data on wildlife use of the marsh and its productivity for downstream habitats.

Water quality analyses conducted thus far indicates that the marshes provide additional treatment to the effluent but that it will be necessary to control algae growth in order to consistently meet water quality objectives. Control of algae blooms is particularly critical if receiving water objectives for undissociated ammonia are to be met.

Both achievement of water quality objectives and better waterfowl habitat can probably be achieved by modifying the layout of the marsh areas to increase water management options. This can be most easily done at Mt. View by expanding the pilot project to include Area C across the drainage channel from the present areas. This area could be flooded and drained as necessary for optimum plant growth and vector control.

In conclusion, the pilot project thus far has yielded considerable information necessary for the design and operation of a marsh for the benefit of wildlife.

647. Nute, J. W., and F. C. Demgen. 1977. Marsh Enhancement Program - Conceptual Plan. Mt. View Sanitary District. Contra Costa County, CA.

648. Nute, J. W., and F. Demgen. 1979. The Wetlands Wastewater Management Alternative. In J. C. Sutherland and R. H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI. Mt. View, CA.

Mt. View Sanitary District, located east of Martinez, Contra Costa County, California, within the San Francisco Bay metropolitan area, provides secondary treatment for wastewater from a population of approximately 14,000 using the two-stage biofiltration process. Since 1954 the District has developed a valuable wildlife habitat by flooding nine acres of man-made wetlands adjacent to the plant with the treated effluent. In 1978 the wetlands system was expanded by construction of three additional plots on ten additional acres. This wastewater reuse project, providing valuable environmental benefits, has been developed by the District as an alternative to disposal through a costly deep water outfall to Suisun Bay.

Environmental benefits of the wetlands system include improved wildlife habitat, utilization of aquatic life forms to improve water quality and establishment of a valuable recreational and educational resource. The wetlands system is managed with the objective of achieving a flourishing wildlife habitat through use of nutrients in the wastewater to produce a living ecosystem of vegetation and aquatic organisms to be utilized by higher forms of life for food and shelter. Aquatic life forms also improve water quality by utilizing algae, detritus and organic pollutants as food. Through management, a balance of emergent vegetation and open water areas with adequate water circulation is reached. This is important to attract migrating ducks who need vegetation for food, protection and occasionally for nesting. The District's freshwater wetlands supports 86 species of birds, 20 species of animals, as well as 33 species of aquatic invertebrates.

Flow through the wetland pond system is by gravity. Thus, no energy is required for moving or pumping the water. Circulation and mixing, as well as surface aeration, is provided by the prevailing winds. Solar energy regulates the natural biologic processes developed within the wetlands ecosystem. Artificial substrate, "Ecofloats" are installed in open water areas to provide habitat for aquatic invertebrates near the surface of the water where oxygen levels are highest.

Adequate water circulation and mosquito fish (*Gambusia afinis*) are the major means for controlling mosquito populations. All ponds must be stocked with mosquito fish in the spring and maintained in proportion to the aquatic invertebrate population. (AA)

649. Nute, J.W., and W.E. Nute. 1979. Marsh/Forest Demonstration Project Feasibility Assessment. J. Warren Nute, Inc. San Rafael, CA. 15 pp.

650. Oberts, G.L. 1981. Impact of Wetlands on Watershed Water Quality. pp. 213-226. *In*: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

A nonpoint source water quality sampling study was conducted on six rural and 11 urban watersheds in the Minneapolis-St. Paul Metropolitan Area (2,968 square miles). Wetland occurrence was one principal watershed selection criterion because wetlands were expected to play a major role in determination of watershed water quality. Regionally, wetlands comprise approximately 7.4 percent of the total seven-county area; wetland percentages in the sampled watersheds vary from 4.8 to 16.3 in the rural basins and from 0 to 14.5 in the urban basins. Results of the water quality monitoring show that wetlands occurrence relates to the annual watershed loads for several sampled constituents. Multiple regression statistical modeling of the sampled watersheds yields significant relationships when various combinations of wetland-related watershed factors are evaluated.

651. O'Brien, P., and J.W. Mitsch. 1980. Root Zone Nitrogen Simulation Model for Land Application of Sewage Sludges. Ecological Modelling 8:233-257.

A root zone nitrogen simulation model was designed to evaluate long term effects of various sewage sludge and ammonia N fertilizer applications upon soil root zone N effects. Specific effects studied were root zone N build-up, crop N uptake (as a percentage of applied N), crop yield and nitrate N leaching. Model results showed that nitrate N leaching had a direct linear relationship to the simulated sludge application rates. For each metric ton of sludge incorporated into the farm soils, the leaching rate increased 21 kg/ha/yr. The leaching rate increased 22 kg/ha/yr for each metric ton of sludge incorporated into the stripmine soils. Leaching rates 50% lower than incorporation amounts resulted from surface application of sludge. The maximum uptake of N was determined from Michaelis-Menten/Monod kinetics to be 135 kg/ha/yr for an incorporated loading rate of 25 metric tons/ha/yr. Over a 50 year period organic N in the root zone build-up due to sludge application rates of 25 metric tons/ha/yr would range from 8,400 to 10,000 kg/ha, depending on the site. Simulated application of 300 kg/ha/yr of ammonia N gave a 98 kg/ha/yr crop N yield, representative of an average yield for the U.S. corn belt. Most of the model findings were in agreement with literature values. (WR)

652. O'Brien, W. J. 1980. Engineering Assessment: Use of Aquatic Plant Systems for Wastewater Treatment, pp. 63-80. In S. C. Reed and R. K. Bastian (eds.), Aquaculture Systems for Wastewater Treatment: An Engineering Assessment. EPA-430/9-80-007. U.S. Environmental Protection Agncy, Office of Water Program Operations. Municipal Construction Division. Washington, DC.

Aquaculture, the production of aquatic organisms under controlled conditions, has been practiced for many centuries to produce food, fiber, and fertilizer. This legacy is both a boon and a liability when the feasibility for using aquatic plants in municipal wastewater treatment is evaluated. In the first place, the terms "aquaculture" and "aquatic plants" are much too broad to permit meaningful analysis of wastewater treatment systems unless boundary conditions are established. The boundaries used in this assessment are: 1) The aquatic plants used in the treatment processes are free floating macrophytes; 2) The primary objective of the treatment system is wastewater renovation. Byproduct recovery is a useful adjunct to this objective but it is of secondary importance, and; 3) Aquatic plant treatment processes can be used to replace, or upgrade existing conventional treatment processes but they must successfully compete with these processes in terms of performance, reliability, and total costs.

Another restriction imposed upon this assessment is limitation of the plant species to water hyacinth, *Eichhornia crassipes*, and duckweed, *Lemma* sp.

653. O'Brien, W.J., 1981. Use of Aquatic Macrophytes for Wastewater Treatment. J. of Environ. Eng. Div., Amer. Soc. of Civil Eng. 107(4):681-698.

654. O'Connor, D.J., R.V. Thomann, and D.M. DiToro, 1973. Dynamic Water Quality Forecasting and Management. NTIS No. PB-225 048/8. Ecological Research Series Rpt. No. EPA-660/3-73-009. August.

The formulation and initial verification of two modeling frameworks are described. The first is directed toward an analysis of the impact of the carbonaceous and nitrogenous components and wastewater on the dissolved oxygen resources of a natural water system. The second modeling framework concentrates on the interactions between the discharge of nutrient, both nitrogen and phosphorus, and the biomass of the phytoplankton and zooplankton populations which result, as well as incorporating the overall impact on dissolved oxygen. The models are formulated in terms of coupled differential equations which incorporate both the effect of transport due to tidal motion and turbulence, and the kinetics which describe the biological and chemical transformations that can occur. The modeling frameworks are applied to the Delaware and Potomac estuaries in order to estimate the ability of such models to describe the water quality effects of carbon, nitrogen, and phosphorus discharges. The agreement achieved between observation and calculation indicate that the major features of the impact of wastewater components on eutrophication phenomena can be successfully analyzed within the context of the models presented.

655. Odens, D. 1976. Suitability of Lagoon Effluents for Irrigation in South Dakota. Completion Rept. 1 (1 July 1975-3 June 1976) to Office of Water Research and Technology. Dept. of Civil Engineering, South Dakota State Univ. Brookings, SD. 46 pp.

An evaluation and classification of lagoon effluents in South Dakota was made with respect to their suitability for irrigation. An estimate of the quantity of water available was also made. Lagoon waters from 20% of the total number of lagoons were sampled and analyzed during July and August. The water quality of the lagoon waters was compared to published water supply quality data for the respective water supply. From these comparisons, empirical relationships were developed permitting the prediction of lagoon water quality on the basis of published water quality data. Using these relationships, all lagoon waters were classified with respect to their suitability for irrigation. Estimates of volume of water available for irrigation were based on area of existing lagoons. (NT)

656. Odum, E. P. 1978a. Value of Wetlands as Domestic Ecosystems, pp. 9-18. In J. H. Montanari and J. A. Kusler (eds.), Proceedings of the National Wetland Protection Symposium held 6-8 June 1977 at Reston, VA. FWS/OBS-78/97. U.S. Fish and Wildlife Service, Washington, DC.

657. Odum, E. P. 1978b. The Value of Wetlands: a Hierarchical Approach, pp. 16-25. In P. E. Greeson, J. R. Clark, and J. E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. Pro-

The value of wetlands is being recognized in political and economic circles; however, the means for quantifying values for decision purposes are yet to be developed. The hierarchical approach to determining the values involves a consideration of component levels (for example, population), ecosystem levels, and global levels. In ecosystems, values are implied for hydrologic considerations and productivity. Waste assimilation and the role of wetlands in global cycling and atmospheric stability form the highest level. Several approaches for summing the values that accrue to the various hierarchical levels are possible, including the common denominator approach, the scaling and weighting approach, and the replacemlent value approach. The latter seems to be more acceptable to economists, because one can make an accurate estimate of the monitary costs associated with the loss of a "free" service performed by a wetland ecosystem. (AA)

658. Odum, H.T. 1978. Principals for Interfacing Wetlands with Development, pp. 29-56. In: M. Drew (ed.), Environmental Quality Through Wetland Utilization. Coordinating Council on Restoration of the Kissimmee River Valley and Taylor Creek-Hubbin Slough Basin.

1087. Odum, H.T. In press.

659. Odum, H. T., and A. F. Chestnut. 1970. Studies of Marine Estuarine Ecosystems Developing With Treated Sewage Wastes. Annual Report for 1969-1970. Accession No. PB 199537. 364 pp.

660. Odum, H. T., A. F. Chestnut, M. Beeston, J. Day, and C. R. Dillon. 1970. Studies of Marine Estuarine Ecosystems Developing with Treated Sewage Wastes. Annual Rept. 1969-1970. Institute of Marine Sciences. Univ. of North Carolina, Morehead City, NC. 366 pp.

The report concerns developments in a study of ecologial systems that develop when the treated wastes from municipal sewage systems flow into estuarine waters. Studies by a team of faculty and students of the University of North Carolina are considering a small marsh-lined estuary, Calico Creek, which receives the wastes following secondary sewage treatment and a set of three ponds in which estuarine water and treated sewage mixture flows. Three control ponds receive tap water and estuarine water. Now in their second year, the ponds are rich in productivity with successive algal blooms throughout the year and a food chain culminating in blue crabs. In this report there are chapters on the events in the salinity regime and input management, photosynthetic productivity and respiration, algal growth, P and N, bacteria, and animal populations. The presence of a substantial ecological system suggests a viable intermediary system interface is possible between man's municipal wastes and normal estuaries. These systems have potential for aquaculture and waste amelioration. (AA)

661. Odum, H. T., and S. Brown. 1976. Regional Implications of Sewage Effluent Application on Cypress Domes, pp. 329-330. In D. L. Tilton, R. H. Kadlec, and J. C. Richardson (eds.), Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

The regional balance of swamps and man are considered for wetlands districts of Florida using models, simulations, energy evaluations, energy quality, measurements of water, and the investment ratio principle. Five special examples given include a long range model of basin formation and landscape maintenance; record of sewage in swamps at Wildwood (FL); development density and water priority with energy investment ratio; contracting water and energy quality; regional model of water, energy, land use, and nutrients in the green swamp district of Florida. (AA)

662. Odum, H. T., K. Ewel, W. Mitsch, and J. Ordway. 1975. Recycling Treated Sewage Through Cypress Wetlands in Florida. Occasional Publ. No. 1. Center for Wetlands. Univ. of Florida, Gainesville.

663. Odum, H. T., and K. C. Ewel. 1978. Cypress Wetlands for Water Management, Recycling and Conservation. Fourth annual report, Center for Wetlands, University of Florida, Gainesville. 953 p.

Recycling of treated sewage wastewaters into two cypress domes in Gainesville, Florida is in its fourth year with much accelerated growth of cypress trees and recharge of groundwater after removal of most of the nutrients and microbes by the natural filter mechanisms of the swamps. The cypress swamps through the shielding effect of their thin leaf cover and their leaf drop in dry season save water, as compared to open water storage. Extension of studies to a cypress strand at Waldo receiving sewage for 43 years showed the long-term stability of the ecosystem receiving the nutrients. Drawdown of superficial groundwaters was found to occur a half mile from canals in South Florida. Lowering the water tables reduced the productivity and temporarily reduced transpiration. Evaluations showed that cypress swamp substitution for technological tertiary treatment was feasible. (NT)

664. Odum, H. T., and K. C. Ewel (eds.). 1980. Cypress Wetlands for Water Management, Recycling and Conservation. Fifth and Final Report. Center for Wetlands, Univ. of Florida, Gainesville. 291 pp.

This is the final report to National Science Foundation and the Rockefeller Foundation on results of research grant: "Cypress Wetlands for Water Management, Recycling, and Conservation." Results given in the first four project reports are not repeated, but new data obtained in 1977-1979 are included. Also included are summaries of the results and implications for management. A book entitled Cypress Swamps reporting all results is being prepared for publication for the Center and is forthcoming from University Presses of Florida.

Recycling of treated wastewaters in cypress domes has now had 5 years of testing and appears to be feasible. This method is preferable to technological treatment because it costs less; it is better than release on uplands because better filtration exists and less ecosystem change is required; and it is preferred to release in open waters because the swamp ecosystem adapts better to high nutrients and low oxygen conditions. In Florida, workshops and discussions with state authorities have led to considering this alternative for tertiary treatment and for storm runoff on a case-by-case basis.

A surprising discovery is the savings of water from evapotranspiration by upland swamps as compared to open water. Comparative studies show that wetlands' photosynthetic productivity ranged from very low to very high depending mainly on the amount of flowing water and the nutrients in the trajectory. Energy evaluations show the swamps to be a major way to both save energy and use solar energy for useful economic purpose, thereby saving waste treatment costs and maintaining a supply of high quality timber.

A series of smaller projects has been initiated with the National Science Foundation and other agencies to prove long-term feasibility, to determine the best loading for wastewater addition to flowing swamps, and to test other kinds of wastewater, such as those containing sulfates and those from phosphorus mining. The Center for Wetlands, which has started with funds from this project, has recently received an increased level of funding from the university. A variety of projects on mangroves, marshes, and other swamps continues as significant research activities aimed at increasing our understanding of the basic and applied aspects of wetlands and their symbiosis with humanity. Other work considers regional aspects of water and energy of wetlands.

The unburned cypress pond receiving treated sewage wastes continues to show healthy tree growth, to maintain a layer of duckweed most of the year, and to allow fast growth of planted seedlings where light is adequate. In order to test for self-regeneration and long-range management options, sewage flow to the burned pond was eliminated 2 years ago. Seedling regeneration has not yet occurred. Seed supply is adequate but exceptionally high waters in what is usually the dry period of both years prevented germination or drowned the seedlings.

The conditions necessary for substantial natural regeneration and their frequency have yet to be established. Funds obtained from Environmental Protection Agency allow continuation of the experiment for another year beyond the NSF-Rockefeller projects, and other funds are being sought so that the means to establish long-range sustenance of wetland ecosystems can be determined. (AA)

665. Odum, H.T., K.C. Ewel, W.J. Mitsch and J.W. Ordway. 1977. Recycling Treated Sewage Through Cypress Wetlands in Florida. pp. 35-67. In: F.M. D'Itri (ed.), Wastewater Renovation and Reuse. Marcel Dekker, New York.

666. Odum, H. T., K. C. Ewel, J. W. Ordway, and M. K. Johnston. 1975. Cypress Wetlands for Water Management, Recycling and Conservation. Second Annual Report. Center for Wetlands, Univ. of Florida, Gainesville. 817 pp.

Studies of water, nutrients, geological process, chemical cycles, microbes, vegetation, forestry, wildlife, economics, energetics, and systems are being made in field tests and in comparisons with other swamp sites. Treated sewage from a trailer court is flowing at 1 inch per week into two cypress domes, one severely burned and one unburned. The burned sewage dome, originally perforated with soil pits and water-jetted wells, leaked some coliform bacteria and virus into the groundwater in the first year. Now, in its second year, it is retaining nutrients, heavy metals

and micro-organisms. Both sewage domes have anaerobic water and a heavy cover of duckweed, but decomposition of organic matter in this semi-natural anaerobic digester is as fast as in aerobic domes. So far, the cypress swamps seem to be a feasible alternative for wastewater recycling, using the semi-natural interface swamp ecosystems for improving water quality and recharging groundwaters. (NT)

667. Odum, H. T., K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.). 1976. Cypress Wetlands for Water Management, Recycling, and Conservation, Third Annual Report. Center for Wetlands, Univ. of Florida. Gainesville. 879 pp.

This is the third annual report on the Cypress Wetlands project sponsored by the Rockefeller Foundation and the RANN Division of the National Sciences Foundation. Studies of water budget and geology show how cypress domes store and save water compared to reservoirs. Experiments with recycling treated sewage water show that the cypress basins (domes) filter nutrients, microbes, heavy metals, and virus, improving the water as the sewage water recharges groundwater. Measurements and systems models show budgets of phosphorus, nitrogen, and carbon, and the role of trees, shrubs, sediments, duckweed, and sedimentation in processing materials, productivity, total metabolism, and building ecological patterns. Comparisons are made with strands and floodplains. Regional studies consider the quantitative role of swamps in water and nutrient budgets of four counties and the south Florida region. (NT)

668. Odum, H. T., K. C. Ewel, J. W. Ordway, M. K. Johnston, and W. J. Mitsch. 1974. Cypress Wetlands for Water Management Recycling and Conservation. First Annual Report. Center for Wetlands, Univ. of Florida, Gainesville. 947 pp.

669. Okorie, P. E. 1976. Effect of Sewage Effluent in Cypress Ponds on Surrounding Soil Moisture and Nutrient Content and on Growth of Pine Trees, pp. 438-472. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

670. Ordway, J. W. 1976a. General Costs for Cypress Wetland Recycling. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

671. Ordway, J. W. 1976b. General Site Selection, Design Criteria, and Costs for Recycling Wastewaters through Cypress Wetlands. Master's Thesis. Univ. of Florida, Gainesville, 54 pp.

672. Ordway, J. W. 1976c. New phases: Waldo, a Strand Receiving Sewage, pp. 803-811. *In* H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation, Third Annual Rept. Center for Wetlands. Univ. of Florida, Gainesville.

673. Ordway, J.W. 1976d. The Projected Cost of Cypress Wetland Disposal for Waldo, Florida. pp. 803-811. *In*: Third Annual Report on Cypress Wetlands, University of Florida, Center for Wetlands, Gainesville.

The general costs for using cypress wetlands as recycling sites for secondarily treated sewage are considered for the city of Waldo, Florida. Using one preliminary design, the total cost for this wetland treatment site was 42.2 cents per 1000 gallons compared with 62 cents per 1000 gallons for spray irrigation and 106 cents per 1000 gallons for advanced waste treatment.

674. Ornes, W.H., and D.L. Sutton. 1975. Removal of Phosphorus from Static Sewage Effluent by Water Hyacinth. Hyacinth Control J. 13:56-58.

675. Ornes, W.H. and K.K. Steward, 1973. Effect of Phosphorus and Potassium on Phytoplankton Populations in Field Enclosures. Agricultural Research Service, Ft. Lauderdale, FL. NTIS No. PB-231 650. May 14 p.

Some of the parameters involved in the addition of nutrients to a marsh environment are evaluated. The effect of weekly applications of phosphorus and potassium on algal populations in artificially isolated segments of a natural marsh environment was monitored. Applications were made to field enclosures for 22 weeks. The treatment rates were equivalent to the quantities contained in 2.5 cm/ha of sewage effluent with a concentration of 10 mg/liter P and 20 mg/liter K. The rates were arbitrarily chosen and were similar to rates recommended for terrestrial application. Phytoplankton blooms and dynamic shifts in dominant phytoplankton genera resulted. Also, the aquatic macrophytes *Chara* and *Utricularia* disappeared after 22 weeks of treatment. Both polluted and clean water phytoplankton genera appeared in the control and treated enclosures. The experiment results indicated a disrupted environment. More study should be conducted before utilizing the sawgrass marshes as living filters for wastewater.

676. Oron, G. et al. 1979. Algae/bacteria Ratio in High-rate Ponds Used for Waste Treatment. Applied and Environ. Microbio., 38(4):570-576.

677. Oswald, W.J. 1973. Productivity of Algae in Sewage Disposal. Solar Energy, 15: 107-117.

678. Oswald, W.J. et al. 1953. Algal Symbiosis in Oxidation Ponds. II. Growth Characteristics of *Chlorella pyrenoidosa* culture in sewage. Sewage Ind. Wastes, 25: 26-37.

679. Oswald, W.J. and H.B. Gotaas. 1957. Photosynthesis in Sewage Treatment Trans. Am. Soc. Civ. Eng. Eng., 122:73-105.

680. Ozimek, T. 1978. Effect of Municipal Sewage on the Submerged Macrophytes of a Lake Littoral. Ekologia Polska 26:3-39.

681. Palmer, H. V. R. 1971. Research Project Appears to Hold Special Promise for Towns, Fishing. National Fisherman. Camden, ME. 52(5):20-24.

682. Palmer, M., and S. T. R. Espirito. 1980. Environmental Study of the Tagus Estuary. Nature and Resources - UNESCO 16(3):14-21.

The Tagus Estuary of Portugal has been severely degraded by the introduction of industrial and municipal wastes and nonpoint source pollution contributions. A research project was organized to document the extent of estuarine pollution, its impacts on the environment and industry, and remedial measures. The estuary is an important regional resource, as it is used for transport, aquaculture, urban and agricultural water supply, and recreation. (EL)

683. Parizek, R. R. 1973. Site Selection Criteria for Wastewater Disposal - Soils and Hydrogeologic Consideration, pp. 95-147. *In* W. E. Sopper and L.T. Kardos (eds.), Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Pennsylvania State University Press.

684. Parker, C.D. and G.P. Skerry, 1968. Function of Solids in Anaerobic Lagoon Treatment of Wastewater: J. Water Pollut. Control Fed. 40(2): 192-204.

Field studies of anaerobic lagoons in Australia have shown that solids farther from the inlet of a lagoon are more active in purification than those deposited closer to the inlet, although in many cases they show lower gas yields. Lagoon sludge purification index (lbs BOD/acre/day/lb vs) values ranged from 0.0053 during the winter at a typical pond inlet to 0.00902 during the summer at the pond outlet. The organic load to the pond during this period was about 482 lbs BOD/day/acre, and the sludge gas yield varied from 1.2 to 7.7 ml/day/gvs. The presence of algae in pond supernatant apparently does not reduce the sludge's BOD removal capacity.

Where methane fermentation is inhibited, BOD can still be removed by sulfate reduction. Laboratory studies showed that a substantial increase (almost 30%) in BOD removal can be achieved by mixing sludge with the supernatant, and that algae proliferate readily in media with high organic contents.

685. Parker, D. S. 1976. Performance of Alternative Algae Removal Systems. In E. F. Gloyna (ed.), Ponds as a Wastewater Treatment Alternative. Center for Research in Water Resources. Water Resources Symposium No. 9. Univ. of Texas Press, Austin.

686. Parker, P. E. 1974. A Dynamic Ecosystem Simulator. Ph.D. Diss. Univ. of Michigan, Ann Arbor.

687. Parker, P. E., P. K. Gupta, K. R. Dixon, R. H. Kadlec, and D. E. Hammer. 1978. REBUS: A Computer Routine for Predictive Simulation of Wetland Ecosystems. Report to the National Science Foundation. NSF ENV 76-80708. Univ. of Michigan, Ann Arbor.

688. Parker, P. E., and R. H. Kadlec. 1978. A Dynamic Ecosystem Simulator. Paper presented at the American Institute of Chemical Engineers 78th National Meeting, Salt Lake City, UT. August 1978.

689. Parrott, H. A., and D. H. Boelter. 1977. The Use of Peat Filter Beds for Wastewater Renovation at Forest Recreation Areas. Presented at a Symposium on Municipal Wastewater and Sludge Recycling on Forest Land and Disturbed Land. Philadelphia, PA.

690. Patel, P. M., A. Wallace, W. L. Berry, and O. R. Lunt. 1978. Reclaimed Sewage Water: A Hydroponic Growth Medium for Plants. Resource Recovery and Conservation 3(2):191-199.

Crops of cucumber, tomato, lettuce and chrysanthemum have been grown in flow culture with secondary sewage effluent as the nutrient source. Energy was saved because fertilizers were not necessary. Cu, Zn, Mn, Fe, Ni, and Pb were removed from the water by the plants so that it could be used for other biologically-based processes where heavy metals might cause problems. Variable amounts of nitrates and phosphates were stripped from the water, and these amounts could be increased at the expense of crop production. (AL)

691. Patrick, R. 1976. The Role of Aquatic Plants in Aquatic Ecosystems. pp. 53-59. *In*: J. Tourbier and R.W. Pierson, Jr. (eds.), Biological Control of Water Pollution. Univ. of Pennsylvania Press, Philadelphia.

Aquatic plants enrich aquatic and wetland ecosystems by fixing carbon and giving off free oxygen during photosynthesis. They also provide shelter for aquatic organisms. In the growth of aquatic plants various nutrients are removed from the water. Nutrients may be accumulated in excess of what is needed for growth. Significant amounts of heavy metals are also accumulated. Nutrients and trace metals are stored in plant tissues and are returned to the aquatic ecosystem as food or detritus. In the case of emergent vegetation, they may be dispersed into the terrestrial ecosystem. Wetlands are important for the production of various substances essential for the aquatic ecosystem. An example is the production of vitamin B12 by fungi and bacteria in swamps.

692. Patrick, W.H., Jr., and R.D. Delaune. 1976. Nitrogen and Phosphorus Utilization by *Spartina alterniflora* in a Salt Marsh in Barataria Bay, Louisiana. Estuarine and Coastal Marine Sci. 4:59-64.

693. Patrick, W.H., R.D. Deluane, D.A. Antie, and R.M. Engler. 1971. Nitrate Removal from Water at the Water-Soil Interface in Swamps, Marshes, and Flooded Soils. Annual Progress Report PFWOA, EPA (Project 1605 FJR, LSU).

694. Patrick W.H., Jr., R.D. Deluane, R.M. Engle, and S. Gotoh. 1976. Nitrate Removal from Water at the Watermud Interface in Wetlands. U.S. Environmental Protection Agency. Ecological Research Series. Washington, DC

Flooded swamp and coastal marsh soils in Louisiana have a high capacity for nitrate reduction, according to reserarch focused: (1) on learning how rapidly, how completely and by what mechanism nitrate is removed by biological reduction from shallow surface water in swamps, marshes and flooded soils, and (2) to determine the oxidation-reduction properties of the water-mud interface that control or influence the reduction of nitrate to nitrogen gas. Oxidized and reduced layers in flooded soil were differentiated according to the vertical distribution of the oxidation-reduction (redox) potential and concentrations of manganous manganese, ferrous iron, sulfide, nitrate and ammonium. Redox potential was measured with a special motor-driven assembly which pushed a platinum electrode through a soil sample at a steady rate. From laboratory experiments, it was found that nitrate added to shallow floodwater rapidly disappeared, oxygen loss from sediments occurred rapidly and nitrate reduction was not inhibited by up to 16 ppm oxygen dissolved in soil suspensions. The nitrate was not reduced in the floodwater but filtered downward into the anaerobic soil layer. Additions of organic matter to a mineral soil flood for rice culture decreased the thickness of the aerobic-anaerobic zone at the soil-water interface and increased the rate of nitrate reduction.

695. Patterson, D. R. 1971. Impact of Effluent Spraying on the Small Mammal Populations and Vegetation of the Disposal Area. Master's Thesis. Bowling Green State University, Bowling Green, OH.

To determine the effect of effluent spraying on the small mammal populations and vegetation of the disposal area, two different systems were selected for study, a woodland disposal system at Seabrook Farms, Seabrook, New Jersey, and a grassland disposal system at the Campbell Soup Company, Napolean, Ohio. Periodic systematic surveys of the vegetation and small mammals had been undertaken by other investigators at Seabrook since the start of the effluent spraying system in 1950. The present study deals with data previously collected by others as well as 1967 and 1969 data collected at Seabrook and 1968-69 data collected at Napoleon by the author.

For the first two or three years of effluent spraying at Seabrook, the mixed-oak woods exhibited an increased rate of growth over reference areas, however, those trees sprayed more than three years began dying, presumably by defoliation and debarking of the trees by the sprayers, thus opening them up to fungal and insect infestation. A decrease in Peromyscus leucopus populations increased in marginally sprayed areas, where the force of the spray was reduced by distance and a dense herbaceous cover which provided cover and a variety and quantity of food. The increase in Peromyscus populations in the marginally sprayed areas may be due to higher pregnancy rates, or invasion of mice into the more favorable habitat. The data from the Campbell spray fields is somewhat inconclusive with only two years of data. (AA)

696. Patterson, J.W., R.A. Minear, and T.K. Nedved. 1971. Septic Tanks in the Environment. NTIS, Springfield, VA.

697. Pavoni, J. L., S. W. Kelber, and G. T. Bablitt. 1974. The Harvesting of Algae as a Food Source From Wastewater Using Natural and Induced Flocculation Techniques, pp. 435-497. In Wastewater Use in the Production of Food and Fiber- Proc. U. S. Environmental Protection Agency. Ada, OK.

698. Payonk, P.M. 1975. The Response of Three Species of Marsh Macrophytes to Artificial Enrichment at Dulac, LA. Master's Thesis. Louisiana State University. Baton Rouge. 122 pp.

This study details the response of three emergent species to treatment with wastewater from a menhaden processing plant. The wastewater significantly increased net above-ground productivity of all species, 38 - 51%. Percentage of applied nutrients actually incorporated into plant tissue was measured. Values ranged from 3.6 - 41.1% for N, and 4.0 - 7.4% for P. Applied nutrients accounted for a 12 - 16% increase in N and P in surface waters of the marsh. The remaining nutrients were accounted for through incorporation into the marsh's soil system, as through limited flushing action. (WE)

699. Payonk, P.M., R.E. Turner and J.H. Stone. 1976. Production, Tissue Nutrients and the Response to Enrichment of Three Marsh Macrophytes in Louisiana. unpbl. manuscript.

700. Pecor, C. H., J. R. Novy, K. E. Childs, and R. A. Powers. 1973. Houghton Lake Annual Nitrogen and Phosphorus Budgets. Tech. Bull. No. 73-6. Michigan Dept. Nat. Res., Lansing. 128 pp.

701. Perry, J.J., D.E. Armstrong, and D.D. Huff. 1981. Phosphorus Fluxes in an Urban Marsh During Runoff, pp. 199-212. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetlands Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

Marshes have frequently been regarded as filters that remove nutrients from water passing through them. A field-oriented study was done to show the effects of an urban marsh on the transport of dissolved and particulate P during runoff events. The marsh was particularly amenable to evaluation because a water budget had been developed for the area and 90% of the water enters the marsh as residential runoff from a gaged storm sewer.

The basic approach involved direct measurement of P input from runoff, precipitation, and groundwater recharge. P output was obtained from P concentrations in surface and groundwater discharge. Laboratory and field investigations were used to calculate the extent of P flux in the marsh by the mechanisms of particulate sedimentation, soil sorption and leaching from vegetation.

The annual dissolved P input was 224 Kg. Approximately 14% of the dissolved P was retained in the marsh, primarily by the mechanisms of sorption during filtration. Seasonal variability in dissolved P retention (6-50%) reflects the capacity of the runoff water to infiltrate the marsh soils. Annual particulate P input was 282 Kg of which 82% was retained by particulate sedimentation. These values do not include release of particulate P originating from the erosion of marsh soils. Reservation should be used in extrapolating the data to other wetlands owing to the unique hydrology in Wingra marsh. (AA)

702. Pershe, E. R. 1980. Combined Aquaculture Systems for Wastewater Treatment in Cold Climates, an Engineering Assessment, pp. 105-127. In S. C. Reed and R. K. Bastian (eds.), Aquaculture Systems for Wastewater Treatment: An Engineering Assessment. EPA-430/9-80-007. U.S. Environmental Protection Agency. Office of Water Program Operations, Municipal Construction Division. Washington, DC.

The purpose of this assessment is to highlight some of the more important aspects of combined aquaculture systems and to evaluate their merit for use in cold climates. Much of the assessment is based on presentations that were made at a seminar held on the campus of the University of California at Davis in September 1979.

703. Peters, R.E. and C.R. Lee. 1978. The Potential of Overland Flow to Treat Runoff Water in the Kissimmee River Valley and Taylor Creek-Nubbin Slough Watersheds, pp. 202-216. In: M.A. Drew (eds.), Environmental Quality Through Wetlands Utilization. Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin. Tallahassee, FL. 243 pp.

Overland flow has been used successfully to treat both industrial and municipal wastewaters for a number of years. Wastewater renovation is achieved through interaction of the physical, chemical, and biological components of the grass/soil system. The most notable example of industrial application in the United States is the use of overland flow to treat cannery wastewater by the Campbell's Soup Company in Paris, Texas.

As part of the mandate in Public Law 92-500 the U.S. Army Corps of Engineers has conducted extensive research on land treatment of wastewater to develop design and operational criteria for cost-effective wastewater treatment systems. A field research facility to investigate overland flow for treatment of municipal wastewater was established near Utica, Mississippi, in the fall of 1975. Results indicate that overland flow can reduce applied nitrogen concentrations of 20 mg/l to below 5 mg/l, representing a mass nitrogen reduction of up to 90%. However, only moderate reduction of phosphorus has been achieved. BOD and suspended solids have been reduced to 10 and 15 mg/l, respectively.

Overland flow has potential for reducing pollutants from both point and nonpoint sources in the Kissimmee River watershed. Three alternatives appear to have the most potential:

a. Effluents from dairy stabilization ponds or lagoons may be spray or flood irrigated onto adjacent pasture for overland flow treatment.

b. Storm-water runoff from improved pasture, citrus groves, or other agriculturally oriented areas may be collected in detention ponds and spray or flood irrigated onto adjacent lands at a lower, controlled rate to enhance nutrient removal and water use by agricultural crops.

c. In lieu of storm water detention, a third alternative is to build a broad, base terrace at near zero channel grade to promote infiltration and evapotranspiration of storm water runoff where soil conditions permit.

704. Peverly, J.H. 1982. Stream Transport of Nutrients Through a Wetland. J. of Environ. Qual. 11:38-42.

The potential of managed wetlands to remove nutrients from agricultural drainage water was investigated by hydrographic and nutrient analyses for 2 years in Oak Orchard Creek, NY, which drains in series cultivated Histosols (upstream) and wetlands managed for waterfowl (downstream). Three stations were established, two above and one below the wetland. Creekwater pH averaged about 7.4. Dissolved concentrations (mg/liter) ranged from 0 to 19 for N, 0.009 to 2 for P, 2 to 10 for K, 45 to 411 for Ca, and 10 to 102 for C, and were highest just below the cultivated areas. Eighty to ninety percent of the creek load was carried from December through March. The cultivated organic soils were a rich source of nutrients to the creek, and the managed wetlands acted as net nutrient sinks for N and P during the second year only, when flow through the system was about half that in the first year. However, on an areal basis, much less nutrient material was lost from the wetlands than from other parts of the basin. The creek system seems to be N-limited; P loads exceeded N loads during late summer. It is suggested that nutrient retention by wetlands depends on past nutrient history and current regulation of water movement through the system. (AA)

705. Piecynska, E., V. Sikorska, and T. Ozimek. 1975. The Influence of Domestic Sewage on the Littoral Zone of Lakes. Polish Archives of Hydrobiology (Polskie Archiwum Hydrobiologii) 22:1141-1456.

706. Pilling, J. R., II. 1978. Design of a Marsh/Pond Sewage Treatment System for a 10-unit Housing Development. Master's Thesis, Department of Landscape Architecture and Regional Planning, Univ. of Pennsylvania, Philadelphia. 74 pp.

This project was entered into under contract with a private developer for a 10-unit housing development on a 250 acre site in Buckingham Township, PA. An investigation of three alternative biological sewage treatment systems, a summary of legal requirements for such a system, a site assessment and suitability analysis of the site to accomodate biological treatment, and a draft design for a marsh/pond sewage treatment system are included in the report. The marsh/pond system used is an adaptation of the technology developed at Brookhaven National Laboratory. (EP)

707. Pirrung, D. F., 1978. Feasibility of Utilization of a Wetland for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent. Presented at American Water Res. Conf., Wisconsin Section, February.

The objective of this study was to evaluate alternative methods for cost effective and environmentally sound treatment of secondarily treated effluent from the Waupun City, Wisconsin, wastewater plant. One of the alternatives was to discharge the effluent to Horicon Marsh, a State and National Wildlife Refuge, for tertiary treatment. This alternative, based on 30/30 mg/liter effluent limits exhibited an estimated present worth cost savings of 1.8 million dollars when compared to conventional treatment. (WE)

708. Pirrung, D.F. 1979. Feasibility of Utilizing a Wetland for Tertiary Treatment. In: J.C. Sutherland and R.H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a Conference held 10-12 July 1979.

The City of Waupun, located in east central Wisconsin, presently discharges secondary effluent from its wastewater treatment plant to the South Branch of the Rock River. The Wisconsin Department of Natural Resources has established very strict effluent limits for the discharge of the City of Waupun wastewater treatment plant to the Rock River. To meet the effluent requirements for discharge to the Rock River, the City of Waupun wastewater treatment plant would require upgrading of the primary and secondary units plus tertiary treatment. The requirements for tertiary treatment are quite stringent and would require very sophisticated, energy intensive, unit processes.

The City of Waupun 201 Facilities Plan, prepared by Donohue & Associates, Inc., evaluated various alternate discharge points and unit processes in order to obtain the most cost-effective and environmentally sound alternative. One of the alternatives was to discharge the secondary effluent from the wastewater treatment plant to a wetland. The Horicon Marsh, a national wildlife refuge, is located approximately five miles east of the City of Waupun.

The feasibility of utilizing a wetland for nutrient removal from secondary municipal wastewater treatment plant effluent consisted of the following tasks: a review of the literature, site visitations of similar projects in Wisconsin and Michigan, evaluation of the wastewater characteristics, and preliminary site investigations.

The purpose of the wetland alternative was to provide the City of Waupun with a less costly simplified wastewater treatment system which is environmentally sound. The marsh alternative considered upgrading of the primary and secondary treatment units plus dechlorination, an effluent pumping station and a transmission line to the wetland. Preliminary costs for conventional tertiary treatment were compared to the cost of discharging the secondary effluent to the wetland. Similar projects throughout the nation, the present state of art, governmental and public input regarding the concept are discussed. (AA)

709. Polin, B. E. 1977. Re-use of Treated Wastewater: A Summary Statement. Rept. No. 50. Water Research Foundation of Australia, Kingsford, N.S.W. 60 pp.

The possible uses of treated or partially-treated sewage for agricultural, aquacultural or domestic purposes are reviewed, with examples of the current application of such systems in Australia. Recent experience of these methods as a means of conservation of water supplies and recharging of groundwater sources is drawn upon in order to assess their present and likely future potential in Australia. It is concluded that direct re-use of treated effluent for supplementing drinking water supplies is inadvisable in the present state of knowledge, and that scarce supplies of first-class water should be reserved for drinking while water of poorer quality could be made available for alternative uses. Some published data regarding water consumption by typical households are compared, and details of small-scale treatment facilities suitable for installation in remote situations are outlined. (AL)

710. Polprasert, C. and P. Edwards. 1981. Low Cost Waste Recycling in the Tropics. Biocycle 22(4):30-35.

711. Pope, P.R. 1981. Wastewater Treatment by Rooted Aquatic Plants in Sand and Gravel Trenches. U.S. Environmental Protection Agency. Municipal Environmental Research Laboratory. Cincinnati, OH.

A patented process developed by the Max Planck Institute (MPI) of West Germany to treat industrial wastes was evaluated as an energy-efficient method to treat municipal wastewater. The major goal was to achieve effluents meeting the U.S. Federal Effluent Standards using this novel biological treatment process that requires a minimal amount of mechanical equipment and manpower for normal operation.

The Moulton Niguel Water District (MNWD) of Laguna, California, constructed and operated an earthen trench system using rooted aquatic plants for the treatment of wastewater. Two trenches in series were planted with the reed *Phragmites* and the bulrush *Scirpus*, respectively.

A 2-month study using conventional secondary effluent as the trench influent showed the system was not effective for removing nitrogen and phosphorus components.

An 11-month study demonstrated that raw screened wastewater applied to the trench system at a rate not exceeding 95 m^3/d (25,000 gpd) could be treated to secondary effluent quality. Spatial requirements were about the same as for a septic tank system.

712. Porath, D., G. Oron, J. Pollock, and A. Richmond. 1981. Ammonia Stripping From Fish Influent by Duckweed in a Circulating System. Presented at the Water Reuse Symposium II. Washington, DC. August 23-28, 1981.

Free floating duckweed (*Lemna gibba*) seems to be an excellent ammonia stripper in the presence of nitrate, as well as other nutrients and wastes found in fish aquaculture. In standard aseptic conditions, about 0.1% fresh duckweed biomass was able to strip ammonia (2.0 - 0.2 mg/l) in the presence of a higher concentration of nitrate (500 mg/l). Slight changes in pH and light did not significantly affect ammonia uptake. About 200 l water taken from a fish aquaculture which contained 02. mg/l ammonia was circulated 5 times a day under the floating duckweed biomass in order to improve contact of the plants with the nutrients. More than 80% of the ammonia content was stripped after 48 hours. Ammonia level was not changed when the circulating system was activated without the duckweed. (AA)

713. Powers, J. E. 1974. Critical Variables in Food-item Population Dynamics in a Wastewater Aquaculture System, pp. 497-509. *In* Wastewater Use in the Production of Food and Fiber-. U.S. Environmental Protection Agency. Ada, OK.

714. Pratt, D. C., V. Bonnewell, N. J. Andrews, and J. H. Kim. 1980. The Potential of Cattail as an Energy Source. Report prepared for the Minnesota Energy Agency, Minneapolis - St. Paul, MN. 147 pp.

715. Prentki, R. I., T. D. Gustafson, and M. S. Adams. 1978. Nutrient Movements in Lakeshore Marshes, pp. 169-194. In R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater Wetlands, Ecological Processes and Management Potential. Academic Press, Inc., New York.

Seasonal P allocation in Typha latifolia L. was investigated by analysis of above and belowground parts in a lakeshore marsh at Lake Mendota, Wisconsin. Maximum total P stocks of 4.3 and 2.2-2.5 g P/m^2 were found in summer and winter, respectively. A maximum upward translocation of 140 mg P/m^2, 1/3 due to mobilization of belowground reserves, was observed the first 2 weeks of June. Over an entire summer, 40% of the 3.2g P/m^2 accumulated aboveground was reallocated from belowground plant parts. However, only 23% of this amount returned to belowground in the fall; 2.5 g P/m^2 was left on the marsh surface as litter plus leachate. Typha roots continued to absorb P past aboveground senescence and into early winter, resulting in post-shoot-death uptake of up to 9% of the next season's P requirement.

Analysis of lakeshore marsh literature via a input-output model suggests that macrophytic translocation of nutrients is an important source of internal loading. In those marshes without major surface water inputs, seasonal accumulation and abandonment of nutrients above the soild interface is likely to be the dominant term in nutrient budgets. (AA)

716. Price, D. 1975a. The Fate of Fecal Coliforms in Cypress Domes. In H.T. Odum, K. C. Ewel, J. W. Ordway and M. K. Johnson (eds.), Cypress Wetlands for Water Management, Recycling and Conservation, Third Annual Report. Center for Wetlands, Univ. of Florida, Gainesville.

717. Price, D. 1975b. The Role of Duckweed in Recycling Sewage Effluent in a Cypress Swamp, pp. 360-382. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

718. Price, D. E., and L. Fox. 1973. Pattern of Distribution of Coliform Bacteria in and Around the Experimental Cypress Dome, pp. 285-308. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

719. Pruder, G.D., J. Carberry and C. Wethe. 1981. Wastewater-molluscan Aquaculture for Lewes, Delaware. EPA report (in preparation).

720. Public Health Service. 1961. Waste Stabilization Lagoons. Proceedings of a Symposium at Kansas City, MO. Aug. 1-5, 1960. PHS, Division of Water Supply and Pollution Control. Washington, DC. 172 pp.

Contents: History of raw sewage lagoons in the midwest; History of oxidation ponds in the southwest; Lagoon research project of the public health service at Fayette, Missouri; Research and installation experiences in California; Virginia's experimental installation; Sewage lagoons in Australia; Economics of waste stabilization lagoons in region VI; Use of stabilization ponds in the United States; Missouri basin criteria; Lagoon development and acceptance in Mississippi; Experiences in Canada; Sewage lagoons and mosquito problems; Lagoon disposal of livestock wastes; Operating experiences in the ten Missouri Basin states; Arctic sewage lagoons. (NT)

721. Queen, W.H. 1977. Human Uses of Salt Marshes. pp. 363-368. In: Ecosystems of the World I: Wet Coastal Ecosystems-Elsevier Scientific Publishing Co., New York.

Present calculations of marsh value emphasize natural characteristics and processes revealed by ecological studies over the past several decades. These characteristics and processes may be grouped into four categories: biological production, aquaculture, wastewater assimilation, and other uses.

Biologically, estuaries bordered by marshes, and coastal waters in the vicinity of extensive marsh-estuarine systems, are among the world's most productive waters in terms of both commercial and sport fisheries. Both estuarine shellfish and many coastal water finfish are doubly dependent on coastal salt marshes. Of equal importance with the habitat role is the function of marshes as producers of nutrient material, especially organic material. Economic demand has stimulated interest in increasing fish and shellfish production in estuarine waters by the use of aquaculture techniques. Although these techniques represent commercial exploitation of marshes, they are independent upon the production of organic nutrients by marsh plants, a natural marsh process. Wastewater assimilation by marsh plants has led to considerable speculation that marshes can be used to partially purify domestic wastewater thereby reducing the need for tertiary sewage treatment. Other marsh characteristics useful to man are erosion control, prevention of damage resulting from tidal flooding, and the cycling of nitrogen and sulphur.

722. Rabe, M. L. 1979. Impact of Wastewater Discharge upon a Northern Michigan Wetland Wildlife Community. Report to the Houghton Lake Sewer Authority, Houghton Lake, MI.

723. Rai, D.N. and J.D. Munski, 1979. The Influence of Thick Floating Vegetation (Water Hyacinth: Eichhornia crassipes) on the Physico-Chemical Environment of a Freshwater Wetland. Hydrobiologia 62(1):65-69.

Physiochemical measurements December 1976-August 1977 of Bhathwa Pokhar, a freshwater wetland at Darbhanga, India, showed that dissolved carbon dioxide was higher and that oxygen, pH and temperature fluctuations were lower under water hyacinth areas than in open water. The extent of difference depends on the time of day and season. Due to extreme hypercarbic and hypoxic conditions most vertebrates living in hyacinth infested areas are air breathers such as water snakes and turtles or supplemental air breathers such as frogs and air-breathing fish. High carbon dioxide and low oxygen concentrations are due to high anaerobic decomposing mat leaves and detritus, increased respiratory activities of organisms, and decreased photosynthetic rates caused by water hyacinth shadowing effects over the water surface. Oxygen is very low under water hyacinth mats (always less than 2 ppm) and during the summer oxygen levels are reduced to zero in both infested and uninfested water areas. Dissolved oxygen reaches its lowest value in late night hours (4 a.m.) and peaks in the afternoon; the maximum value is 7 ppm in clear areas during winter. Bhathwa Pokhar is a shallow (1.5 m mean depth), small (1.5 ha), swampy pond and 98% area is covered by water hyacinth. The source of pond water is Darbhnage Medical College campus sewage.

724. Ramsay, A. 1976. Comparison of Fall Birds Present in a Natural Cypress Dome, a Sewage Dome, and the Adjacent Pine Plantation, pp. 654- . In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling, and Conservation. Third Annual Report. Center for Wetlands. Univ. of Florida. Gainesville.

725. Ramsay, A. 1978. The Effect of the Addition of Sewage Effluent on Cypress Dome Bird Communities. Master's paper. School of Forest Resources and Conservation, Univ. of Florida, Gainesville. 22 pp.

726. Randall, C. W., and L. D. Benefield. 1980. Biological Process Design for Wastewater Treatment. Prentice-Hall, Inc. Englewood Cliffs, NJ. 540 pp.

This volume is a practical treatise on the design of biological effluent treatment plant which bases the calculations employed on an understanding of the theoretical principles involved. The first two chapters are concerned with the fundamentals of process kinetics and microbiology (including growth kinetics) respectively, and are followed by a section on wastewater characteristics and flows. Thereafter, a series of chapters on specific treatment applications is presented, including activated sludge and its various modifications, aeration system design, treatment ponds and aerated lagoons; attached-growth biological treatment methods, and sludge digestion. The problems and processes of nitrification and denitrification are considered where appropriate, in addition to the oxidation of organic matter. (AL)

727. Raschke, R. L. 1968. Algal Periodicity, Primary Production and Waste Reclamation in a Tertiary Sewage Stabilization Pond Ecosystem. Ph.D. Diss. Iowa State Univ., Ames.

728. Reddy, C. N., and W. H. Patrick, Jr. 1977. Effect of Redox Potential and pH on the Uptake of Cadmium and Lead by Rice Plants. J. Environ. Qual. 6: 259-262.

Redox potential and pH are two of the major factors influencing the mobilization and immobilization of heavy metals in flooded soils and sediments, and their availability to plants. A system developed for growing plants in soil suspensions where redox potential and pH can be controlled was used to study the uptake of cadmium (Cd) and lead (Pb) by rice plants (Oryza sativa L.). Uptake of Cd and Pb by root and shoot tissue, and their translocation from root to shoot, was determined at six different redox potentials (-200, -100, 0, +100, +200, and +400 mV) and four pH values (5,6,7, and 8). The effects of redox potential and pH on the levels of water-soluble Cd and Pb in the soil suspensions were also studied. Almost all Cd entering the rice plants accumulated in the shoots. Total Cd uptake and shoot uptake increased with an increase in suspension redox potential and a decrease in pH. Water-soluble Cd in the soil suspension was significantly correlated with total plant Cd and Cd uptake by shoot. Total Pb uptake, including Pb associated with the roots, decreased with an increase in pH. No definite redox potential effect was found on Pb uptake by the shoot. Lead was less mobile than Cd in the rice plants and was primarily associated with the roots. Water-soluble Pb decreased with an increase in redox potential and pH, and was significantly correlated with total plant Pb uptake and Pb uptake by shoot.

729. Reddy, K. R., and D. A. Graetz. 1980. Use of Shallow Reservoirs and Flooded Soil Systems for Agricultural Drainage Water Treatment: Inorganic nitrogen removal. J. Environ. Qual. (in review).

730. Reed, C.A., and T. Kubiak. In press. An Ecological Evaluation Procedure for Determining Wetlands Suitability for Wastewater Discharge/Treatment. In: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters, Proceedings of a Workshop, 23-25 June 1982. University of Massachusetts, Amherst MA. US Fish and Wildlife Service and US Environmental Protection Agency.

731. Reed, S. C., and R. K. Bastian (eds.). 1980. Aquaculture Systems for Wastewater Treatment: An Engineering Assessment. EPA-430/9-80-007. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC. 127 pp.

This publication contains five additional engineering assessments not included in Bastian and Reed (1979).

1088. Reed, S.C. and R.K. Bastian. In press.

732. Reed, S. C., R. K. Bastian, and W. Jewell. 1979. Engineering Assessment of Aquaculture Systems for Wastewater Treatment: an Overview, pp. 1-12. In R. K. Bastian and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division, Washington, DC.

This overview contains a summary of the current status of aquaculture technologies, including a section on wetland treatment processes. For the purposes of this assessment, wetland processes were defined as those treatment processes that take place on land where the water table is at or above the surface for long enough each year to maintain saturated soil conditions and the growth of related vegetation. A number of conclusions and recommendations for further studies are listed for wetland processes and for the other sections of this publication (e.g., aquatic plant systems and combined systems). (EP)

733. Reid, G. W. 1976. Algae Removal by Fish Production. In E. F. Gloyna, J. F. Malina, Jr., E. M. Davis (eds.), Ponds as a Wastewater Treatment Alternative. Water Resources Symp. #9, Center for Research in Water Resources, College of Engineering, Univ. of Texas, Austin.

734. Reim, J. 1980. Sewage Treatment in a Sphagnum Peat Bog. Great Lakes Focus on Water Quality 6(3):6-9.

735. Reimold, R.J., 1980. Marsh Creation: Impact of Pesticides on the Fauna, Use of Infrared Photography, Ditching and Diking. pp. 132-135. In: Rehabilitation and Creation of Selected Coastal Habitats: Proceedings of a Workshop, Sapelo Island, Georgia, 16-20. May, 1976. Fish and Wildlife Service, Biological Services Program, Washington, DC Report FWS/OBS-80/27. November.

Species diversity is used as an indication of the effects of toxaphene on the fauna of two estuarine systems. Brunswick Estuary in Georgia receives toxaphene from a manufacturing plant and from agricultural runoff. The Duplin Estuary is a pristine estuary, part of a National Estuarine Sanctuary. The study covers the period 1968-1976. Except for the early years of the study (1968-1971), no mesurable quantities of toxaphene were found anywhere except very close to the manufacturing plant. Since the study began, the levels of toxaphene in the manufacturing plant effluent decreased from parts per hundred to parts per billion. There was a dramtic change both in the number of species and in the number of individuals over the years. The diversity indices for Terry Creek, the stream into which the toxaphene effluent was discharged, revealed that in 1968 there were only three different kinds of organisms, as opposed to nearly 25 species by 1976. Biomass also increased with time. After the first three years, the number of species remain more constant in the Brunswick Estuary than it did in the natural Duplin Estuary. Color infrared aerial photography is useful for ecological delineation and for economic delineation including legal purposes. Ditching and diking for habitat creation and mosquito control have a variety of effects on marshes. Ditching reduces the water level, can cause invasion of upland species, and reduces the area of vegetated wetland. Another problem with ditching is the creation of cat clays. The various consequences of alteration of the salt marsh ecosystem should be evaluated when ditching or diking is being considered.

736. Reppert, R.T. W. Sigleo, E. Stakhiv, L. Messman, and C. Meyers. 1979. Wetland Values: Concepts and Methods for Wetlands Evaluations. Research Rept. 79-41. U.S. Army Corps of Engineers Institute for Water Resources, Fort Belvoir, VA. 109 pp.

Report presents concepts and methods for the evaluation of wetlands pursuant to Section 404, PL 92-500 (as amended), President Carter's May 24, 1977 Executive Order on wetlands protection, and other statutory and Administrative authorities. The evaluation of wetlands is based on the analysis of their physical, biological and human use characteristics. The report discusses these functional characteristics and identifies specific criteria for determining the efficiency with which the respective functions are performed.

Two potential wetlands evaluation methods are described. One is a non-quantitative method in which individual wetland areas are evaluated based on the deductive analysis of their individual functional characteristics. The other is a semi-quantitative method in which the relative values of two or more site alternatives are established through the mathematical rating and summation of their functional relationships.

The specific functions and values of wetlands which are covered in this report are (1) natural biological functions, including good chain productivity and habitat, (2) their use as sanctuaries, refuges or scientific study areas, (3) shoreline protection, (4) groundwater recharge, (5) storage for flood and storm water, (6) water quality improvement, (7) hydrologic support, and (8) various cultural values.

737. Reynolds, B.J. 1976. An Example of Sewage Disposal by Spray Irrigation, pp. 218-220. In: G. Berg, H.L. Bodily, E.H. Lennette, J.L. Melnick, and T.G. Metcalf (eds.), Viruses in Water. American Public Health Association, Inc., Washington, D.C.

738. Reynolds, J.H. 1981. Land Application of Municipal Wastewater. J. Water Pollut. Control Fed. 53(6):767-769.

739. Rich, L.G. 1980. Low Maintenance Mechanically Simple Wastewater Treatment Systems. McGraw-Hill Book Co., New York. 219 pp.

The basic principles and mechanisms for biological treatment of sewage are summarized and a number of low maintenance, mechanically simple systems, which can reliably treat sewage flows of 1 mgd or less, are described. They comprise activated-sludge systems, lagoon systmes, solids removal and stabilization systems, and fixed-film systems. In addition, land disposal of both sewage and sewage sludge is discussed. The design equations and criteria governing the performance of the various systems are presented as a basis for practical operation and control of the systems in question, with particular emphasis on the fate of the suspended solids and the maintenance of acceptable suspended solids concentrations in the final effluent. (AL)

____. Richardson, B. 1981.

740. Richardson, C.J. 1976. Plant Growth, Nutrient Accumulation and Decomposition in a Central Michigan Peatland Used for Effluent Treatment. Proc. of Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

1089. Richardson, C.J. and D.S. Nichols. In press.

741. Richardson, C. J., J. A. Kadlec, W. A. Wentz, J. P. M. Chamie, and R. H. Kadlec. 1975. Background Ecology and the Effects of Nutrient Additions on a Central Michigan Wetland. Publ. No. 4. Univ. of Michigan, Ann Arbor. 64 pp.

In central Michigan, studies are currently underway to determine the effects of nutrient additions on the structure and function of a wetland (peatland) ecosystem. Field experiments were conducted to determine the effects of nutrient additions on various components of wetland ecosystems. A simulation model was utilized. The underlying purposes of these studies were to test the feasibility of wetlands to remove nutrients from secondarily treated sewage wastewater and to determine the magnitude of any changes in the structure and function of the wetland ecosystem. Parameters discussed in this paper are net primary production, nutrient uptake and transfers, water quality, and decomposition rates. (NT)

742. Richardson, C.J., D.L. Tilton, J.A. Kadlec, J.P. Chamie, and W.A. Wenz. 1978. Nutrient Dynamics in Northern Wetland Ecosystems, pp. 217-241. In: R.E. Good, D.F. Whigham, and R.L. Simpson (eds.), Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, Inc., New York.

Nutrient information was reviewed by compartment (i.e. soils, plants, water) and at the ecosystem lever among 4 northern wetland types: fens, bogs, swamps, and marshes. Total soil N, P, and Ca were lowest in bog peats but the Mg content did not vary appreciably among wetland types. Cation exchange capacity was >100 meq/100 g for all wetlands. Concentrations of N, P, Ca and Mg were significantly lower in bog plants than fen plants. Seasonal patterns of nutrient concentrations (N and P) in leaves and stems decreased through the growing season in fen plants. Translocation of nutrients from plant parts prior to abscission did not occur in the plants studied. Minerotrophic fen water chemistry differed from that of ombrotrophic bogs in that fen waters were dominated by Ca^{++} and HCO_3- ions and bog waters were dominated by H^4 and SO_4^{++} ions (Moore and Bellamy, 1974). Seasonal variations in NH_4-N, NO_3-N and PO_4P were closely related to peatland hydrology, organism uptake and peat exchange characteristics. A cycling study for a central Michigan fen revealed that >97% of the N, P and Ca was in the peat compartment. The turnover time for N in aboveground biomass was 2 years. An examination of plant uptake rates of N and P in the Michigan fen revealed that low plant productivity may be related to low N and P availability. Nutrient outputs for wetland ecosystems, when compared to yields from terrestrial forest systems, indicate that natural outputs for some wetland types are well within the range, or in some cases exceed, outputs from upland terrestrial ecosystems. The capacity of acid peatlands to store or assimilate additional P or K on a long-term basis appears limited. Nutrient dynamics in wetlands at the organism, community and ecoystem level are all poorly understood and are deserving of further study. (AA)

743. Richardson, C. J., W. A. Wentz, J. P. M. Chamie, J. A. Kadlec, and D. L. Tilton. 1976. Plant Growth, Nutrient Accumulation and Decomposition in a Central Michigan Peatland Used for Effluent Treatment, pp. 77-118. In D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of A National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

Studies were performed on the impacts of artificial nutrient loading on peatland vegetation in Michigan. Experiment plots were treated with two, four, and ten times the normal levels of nutrient salts. Short term results indicate that nutrient addition results in the enhancement of growth of some species, tissue concentrations are increased, and litter and organic soils function as a nutrient sink. Specifically, sedge N and P levels and sedge biomass increased over controls in the 4x and 10x plots, but that growth of grass and aster decreased. No changes in litter decomposition rate were noted in any treatment plots, although nutrient levels of plant tissue were significantly higher in the plots that received the lower-level applications (only P was significantly higher in the 4x and 10x plots). Nutrient processing in this system was accomplished by denitrification in soil, sorption by litter and peat soil, and nutrient uptake by plants. The authors conclude that such natural filtering systems offer a short-term solution for removing a limited amount of nutrient input. (EP)

744. Rickards, W. L. 1973. The Feasibility of Penaeid Shrimp Culture in Brackish Ponds Receiving Treated Sewage Effluent. Sea Grant Reprint No. 58. North Carolina State Univ. Raleigh, NC. 10 pp.

The report focuses on a study conducted as an extension of a previous project where penaeid shrimp had been stocked in control and treated sewage ponds -- shrimp grew in control ponds but failed to survive in treated sewage ponds. It has been concluded in the earlier project that low levels of dissolved oxygen in the water at night and wide diurnal pH fluctuations were responsible for shrimp failure. The subsequent project was designed to modify oxygen and pH regimes in a sewage pond and subsequently stock it with shrimp to determine whether or not factors in addition to oxygen and/or pH has been responsible for the previous shrimp mortalities. It was found that shrimp were able to survive and grow in the aerated sewage pond. (NT)

745. Robbins, R., and D. Lagerroos (eds.). 1981. Materials on Floodplains and Wetlands: Legal Restraints and Options. American Bar Association Special Committee on Housing and Development Law. Prepared for a workshop at Chicago, IL, 28-29 January 1981.

746. Roberts, M. H. 1980. Detoxification of Chlorinated Sewage Effluent by Dechlorination in Estuarine Waters. Estuaries 3(3):184-191.

Secondary treated sewage was chlorinated to a residual level of 2-10 mg/l in a continuous flow system in the laboratory and diluted to various levels with estuarine water. A portion of the chlorinated sewage effluent was dechlorinated with sodium thiosulfate and the dechlorinated waste was diluted with estuarine water in the same proportions as the chlorinated waste. *Menidia menidia*, *Palaemonetes pugio* and *Crassostrea virginica* were exposed to chlorinated and dechlorinated treatments. High concentrations of chlorinated effluent caused mortalities in *M. menidia* and *P. pugio*. Similarly, the chlorinated wastes depressed the shell deposition rate of C. virginica below 50% of controls at all doses. (PA)

747. Robinson, A. C. et al. 1976. An Analysis of the Market Potential of Water Hyacinth-Based Systems for Municipal Wastewater Treatment. Battelle Research Rept. BLC-OA-TFR-76-5, Battelle Columbus Lab., Columbus, OH.

748. Roche, W. M., 1973. Wastewater Reclamation and Reuse in the Suisun Marsh, California. pp. 326-335. *In*: Water for the Human Environment, Vol. III, Tech. Sessions, Proceedings of the First World Congress on Water Resources. Chicago. September 24-28.

The U.S. Bureau of Reclamation, Solano Irrigation District, and City of Fairfield are conducting a wastewater reclamation and reuse pilot demonstration program in the Suisun Marsh, Solano County, California. The program objective is to demonstrate the compatibility of beneficial reuse and treatment of municipal and industrial wastewater with marsh management. The program is designed to provide information to assist the local area in meeting its waste treatment and disposal obligations. To provide information on the reuse of wastewater for agricultural purposes, and to provide the Bureau of Reclamation with information on a source of water for meeting its responsibility for protection of the Suisun Marsh. The program evaluates several features which beneficially use wastewater and also remove nitrogen. Field facilities include a detention reservoir, a sprinkler-irrigated and tile-drained pasture, marsh ponds, and irrigated marshland. The facilities are designed to remove 90% of the nitrogen from the wastewater that eventually flows to the marsh channels.

749. Rodgers, E. W. 1976. Everything is Ducky at Vandenberg AFB. Water and Wastes Engineering 13(10):43-44.

750. Roels, O. A., V. Harris, V. Lee, and B. Sharfstein. 1977. Effect of Detergent Legislation on Phosphorus in Effluent and Receiving Waters. J. Water Poll. Control Fed. 49(9):2017-2021.

A small effluent aquaculture system has been operated at the Tallman Island sewage works of New York City since 1972, to remove dissolved inorganic N and P from secondary sewage effluent before discharge to the East river. Regular monitoring has shown a marked increase in the molar N:P culture phytoplankton in this system, and studies have confirmed that this is due to recent state legislation banning the use of P in detergents. This has resulted in a reduction of more than 50% in the production of protein in the aquaculture system. (AL)

751. Rogers, H. H., and D. E. Davis. 1972. Nutrient Removal by Water Hyacinth. Weed Sci. 20:423-428.

752. Rohlich, G. A., and D. P. Uttermark. 1972. Wastewater Treatment and Eutrophication, pp. 231-245. In G. E. Likens (ed.), Nutrients and Eutrophication. Amer. Society of Limnol. Oceanogr., Special Symposia, Vol. 1.

753. Rosman, L. 1978. Impact Assessment of a Northern Michigan Wetland Invertebrate and Vertebrate Fauna Receiving Secondarily Treated Sewage Effluent.

754. Rudolfs, W., L. L. Frank, and R. A. Ragotzkie. 1950. Literature Review on the Occurrence and Survival of Enteric, Pathogenic, and Related Organisms in Soil, Water, Sewage, and Sludges, and on Vegetation. Sewage & Industrial Wastes 22:1261-1281.

1090. Rusincovitch, F. In press.

755. Russell, W.C. et al. 1981. Detergents and Waterfowl. J. of Zoo Animal Sci. 12(1):10-12.

756. Rybczynski, W., C. Polprasert, and M. McGarry. 1978. Low Cost Technology Options for Sanitation: A State of the Art Review and Annotated Bibliography. International Development Research Center and World Bank Report IDRC-102E.

Technologies available for primitive and advanced sewage treatment systems are reviewed. Alternative approaches to collection, treatment, reuse, and disposal of human wastes are presented as an aid to policy-makers and technicians faced with instituting or improving sewage programs. Options for waste disposal in hot climates also are discussed. Included is an annotated bibliography of literature on sewage treatment and handling. The bibliography contains sections on: deposition devices; onsite collection and treatment-pit latrines, composting privy, septic tank and aqua-privy; collection and offsite treatment-cartage, waterborne, ponds, composting, aquatic weeds; reuse-irrigation, aquaculture, algae, fertilization, biogas; greywater; and water conservation. (EL)

757. Ryther, J. H. 1973. The Use of Flowing Biological Systems in Aquaculture, Sewage Treatment, Pollution Assay, and Food-Chain Studies. Tech. Rept. 73-2. Woods Hole Oceanographic Institution, Woods Hole, MA. 506 pp.

A combined tertiary sewage treatment-marine aquaculture system has been designed and successfully tested on a small, experimental scale. In this system, the effluent from secondary sewage treatment, diluted with seawater, is used as a source of nutrients for the growth of unicellular marine algae, and the algae, in turn, are fed to oysters or other shellfish. The algae remove the objectionable constituents from the secondary sewage effluent (ammonia, nitrate, phosphate, etc.) and the algae are removed by the oysters. The products are purified waste effluent, which will not support further algal growth (undesirable "algae blooms") in nature, and a commercially-valuable crop of seafood. Using a continuous flow mode of operation, the process was capable of removing 95-100% of the inorganic nitrogen content of the sewage effluent, the discharge from the system being unable to support further algal growth and often containing less nitrogen than the receiving seawater. (NT)

758. Ryther, J. H. 1974. The Use of Flowing Biological Systems in Aquaculture, Sewage Treatment, Pollution Assay, and Food Chain Studies. Rept. to National Science Foundation. Woods Hole Oceanographic Institution. Woods Hole, MA. 371 pp.

The study is concerned with the growth and nutrient-uptake kinetics of several species of marine phytoplankton. These were studied by means of chemostat culture techniques in an attempt to determine the optimal combination of sewage effluent and seawater in the medium, algal yield, and nutrient utilization consistent with the concept of combined tertiary-treatment aquaculture system. Output from the continuous algal cultures was fed to juvenile oysters in an attempt to determine growth of the molluscs as a function of algal food species. Other, separate experiments were conducted to determine the effect of concentration of a single diatom species, Phaedactylum tricornutum, on the rate and efficiency of food assimilation deposition (as feces and pseudofeces) and growth of juvenile oysters. These and other aspects of the study are fully detailed. (NT)

759. Ryther, J. H. 1975a. Investigative Research and Management of Effluent from Secondary Wastewater Treatment Utilizing a Marine Aquaculture System for Removal of Inorganic Nutrients. Final Report to National Science Foundation. Woods Hole Oceanographic Institution, Woods Hole, MA. 60 pp.

A combined waste recycling-marine aquaculture system capable of complete N removal from treated domestic wastewater has been developed and tested on a pilot-plant scale over a 1 year period. Effluent from secondary sewage treatment, mixed with seawater, is used to grow unicellular marine algae in large, continuous-flow, outdoor mass cultures. Harvest from the algae cultures is fed to oysters and other filter-feeding bivalve molluscs and to secondary crops of flounders or lobsters. Dissolved wastes produced by the animals are assimilated by cultures of commercially-valuable seaweeds. Successful cultures of unicellular algae, mostly diatoms, and seaweeds have been sustained over long periods of time (months) with only minor problems. Bivalve mollusc culture was unsuccessful during the first year of operation. An alternative N-removal system consisting only of seaweeds fed a continuous flow of secondary sewage effluent mixed with seawater has also been evaluated. Year-round operation would be possible in tropical to semi-tropical climates. In temperate climates, operation of the system is possible only on a seasonal basis. (NT)

760. Ryther, J. H. 1975b. Physical Models of Integrated Waste Recycling-marine Polyculture Systems. Aquaculture 5:163-177.

761. Ryther, J. H. 1975c. Preliminary Results with a Pilot Plant Waste Recycling Marine-Aquaculture System. Tech. Rept. No. 75-41. Woods Hole Oceanograhic Institution. Woods Hole, MA. 61 pp.

A combined waste recycling-marine aquaculture system capable of complete nitrogen removal from treated domestic wastewater has been developed and tested on a pilot-plant scale over a one-year period.

Effluent from secondary sewage treatment, mixed with seawater, is used to grow unicellular marine algae in large, continuous-flow, outdoor mass cultures. Harvest from the algae cultures is fed to oysters and other filter-feeding bivalve molluscs and to secondary crops of flounders or lobsters. Dissolved wastes produced by the animals are assimilated by cultures of commercially-valuable seaweeds. Successful cultures of unicellular algae, mostly diatoms, and seaweeds have been sustained over long periods of time (months) with only minor problems. Bivalve mollusc culture was unsuccessful during the first year of operation. An alternative N-removal system consisting only of seaweeds fed a continuous flow of secondary sewage effluent mixed with seawater has also been evaluated. Year-round operation would be possible in tropical to semi-tropical climates. In temperate climates, operation of the system is possible only on a seasonal basis. (NT)

762. Ryther, J. H. 1976a. Preliminary Results with a Pilot Plant Waste Recycling Marine Aquaculture System. Report to the National Science Foundation. Woods Hole Oceanographic Institution. Woods Hole, MA. 46 pp.

A biological, tertiary sewage treatment-marine aquaculture system has been developed, tested, and evaluated over one year on a "pilot-plant" scale at the Environmental Systems Laboratory (ESL) of the Woods Hole Oceanographic Institution. The effluent from secondary sewage treatment, mixed with seawater, is used as a source of nutrients to grow single-celled marine algae in mass, continuous flow-through cultures. Algal cultures diluted with seawater are fed into cement raceways containing stacked trays of shellfish. The trays were stocked with the American oyster (Crassostrea virginia) and the hard clam (Mercenaria mercenaria) as well as smaller numbers of other shellfish species. The phytoplankton remove the nutrients from sewage effluent which has varied experimentally from 10-50% of the effluent-seawater mixture. The shellfish remove the phytoplankton from the water. Prior to its discharge, the effluent from the shellfish cultures is passed through seaweeds grown in suspended culture to remove nutrients not initially assimilated by phytoplankton and excretion from the shellfish. (NT)

763. Ryther, J. H. 1976b. Marine Polyculture Based on Natural Food Chains and Recycled Wastes. Tech. Rept. 76-92. Woods Hole Oceanographic Institution. Woods Hole, MA.

Research has continued during the past Sea Grant fiscal year on the development, testing, and evaluation of a combined waste recycling-marine polyculture system. The concept of the system is to grow unicellular marine algae (phytoplankton) in mixtures of seawater and the effluent from a secondary sewage treatment plant. The algae grown in continuous flow-through cultures, are then fed to bivalve molluscs, such as oysters, clams, scallops, or mussels. The algae remove the nutrients from the wastewater and the molluscs remove the algae. Finfish (winter flounder) and crustacea (American Lobster) are stocked as post-larval or juvenile animals together with the molluscs to feed upon the solid wastes (feces and pseudo feces) produced by the shellfish and upon the small invertebrate fauna (polychaete worms, amphipods, etc.) that are supported by these wastes. Seaweeds constitute a final polishing stage to the system, receiving the effluent from the animal culture system and removing from it nutrients regenerated through excretion and metabolism of the animals as well as any nutrients from the wastewater not initially removed by the phytoplankton. Twelve reports by various authors are compiled in this volume. (NT)

764. Ryther, J. H. 1979. Treated Sewage Effluent as a Nutrient Source for Marine Polyculture, pp. 351-375. *In* R. K. Bastian and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430 9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC.

A biological tertiary sewage treatment-marine aquaculture system was developed, tested, and evaluated for two years on a "pilot-plant" scale at the Woods Hole Oceanographic Institution's Environment Systems Laboratory. The effluent from secondary sewage treatment, mixed with seawater, was used as a source of nutrients to grow single-celled marine algae (phytoplankton) in mass (35,000 gallon), continuous flow-through cultures. Harvest from the algal cultures (experimentally varied from 25% to 75% of the culture volume/day), diluted with seawater, was fed into 40' x 4' x 5' (deep) cement raceways containing stacked trays of shellfish. The latter, stocked at densities ranging from 75,000 to 150,000 animals/raceway (1,500 - 3,000 per tray) have consisted of different species of oysters and clams, and smaller numbers of other shellfish.

The phytoplankton removed the nutrients from the sewage effluent, which varied experimentally from 10 percent to 50 percent in the effluent-seawater mixture. The shellfish removed the phytoplankton from the water. Effluent from the shellfish cultures (i.e., the pond harvest and diluting seawater) prior to its discharge was passed through a culture of seaweeds, grown in suspended culture in raceways adjacent to the shellfish cultures, which serve as a final polishing step, removing nutrients not initially assimilated by the phytoplankton and those regenerated by excretion of the shellfish and decomposition of their solid wastes. After initial experimentation with several seaweed species, research was concentrated on two red algae of potential commercial value, *Gracilaria tikvahiae* and *Neoagardhiella baileyi* (which contain the polysaccharides, agar and carrageenan respectively). (AA)

765. Ryther, J.H. et al. 1972. Controlled Eutrophication-increasing Food Production from the Sea by Recycling Human Wastes. BioScience 22:144-152.

766. Ryther, J.H., T.A. DeBusk, M.D. Hanisak, and L.D. Williams. 1979. Fresh Water Macrophytes for Energy and Wastewater Treatment, pp. 652-660. *In*: P.E. Greeson, J.R. Clark, and J.E. Clard (eds.), Wetland Functions and Values: The State of Our Understanding, Amer. Water Resou. Assoc. Tech. Publ. TPS 79-2. Minneapolis, NM.

Fresh water weed crops aie capable of simultaneously providing advanced treatment (nutrient removal) of wastewater passed through them and produc-biomass that may be converted to fuel by anaerobic digestion. Performance of both functions depends upon the rate of primary organic production of the plant species in question. Annual yields of the floating species, *Lemna minor* (duckweed) and *Eichhornia crassipes* (water hyacinth), and of the submerged species, *Hydrilla verticillata*, were determined in central Florida. Yields of duckweek and *Hydrilla*, 13.5 and 15.3 m tons/ha/year, respectively, are comparable to many temperate terrestrial food and grass crops. The yield of water hyacinths, 88.3 m tons/ha/year, is among the highest documented for any plant species on earth. A one thousand hectare water hyacinth farm is capable of producing 10^{12}BTU of energy per year as methane gas and, at the same time, of removing the nutrients from the wastewater of a population of 700,000 people. (AA)

767. Salmon, J. E. 1973. A Question as to the Possibility of Utilizing Plants Capable of Assimilating Heavy Metals to Practical Ends. Biol. J. Linn. Soc. Abstract. 5:357.

768. Sanders, J.G. and E.J. Kuenzler, 1979. Phytoplankton Population Dynamics and Productivity in a Sewage-Enriched Tidal Creek in North Carolina. Estuaries 2:87-96.

Calico Creek differs from neighboring estuaries in that it receives sewage effluent, and its waters therefore contain ample nutrients. High nutrient levels enable the phytoplankton population, which is probably light-limited, to reach densities of a thousand billion cells/l during the summer, 2 to 3 orders of magnitude higher than the surrounding, nutrient-limited populations. At cell densities greater than 10 million cells/l the number of dominant species is greatly reduced and the level of diversity drops sharply. Calico Creek also differs by being very shallow; the population can be drastically affected by high runoff. The productivity of both the phytoplankton and the surrounding Spartina marsh is much higher than the neighboring unpolluted estuaries. Unlike the larger and more stable estuaries nearby, the dependence of the population on the effluent for nutrients, the possibility of toxic materials entering the creek with the effluent, and its small size make Calico Creek subject to sudden change.

769. Sanville, W. D. 1979. Productivity Response of an Alaskan USA, wetland Plant Community to Nutrient Enrichment. Proceedings of the Alaska Science Conference 30:137. U. S. Environmental Protection Agency, Corvallis Environmental Research Laboratory. Corvallis, OR.

770. Sauze, F. 1975. Algae, a Resource for the Future? From Water Purification...to Aquaculture and Energy Production. Tech. Sci. Munic. (France) 70(12): 537-540.

The role of phytoplankton in solving problems of pollution, protein shortage, and energy replacement is discussed with reference to research throughout the world. Purification of sewage-works effluents by algae in lagoons could produce quantities of plankton, small crustaceans, and molluscs for use as food for higher animals, or as fertilizer. Marine farming presents economic problems but a simpler type of aquaculture, similar to purification lagoons, is visualized for production of carp, eels, or trout. Rotation of crops, such as fodder, rice, and fish, is possible on drainable ponds. Energy production from cellulosic wastes, from the sun via plankton, and by "biophotolysis" of water is also reviewed. (EL)

771. Savannah River Ecology Lab, 1972. Distribution and Cycling of Radioactive Isotopes Released into the Savannah River Swamp Forest: Environmental Implications Progress Report. Nov. 1, 1971 to Aug. 1, 1972. Aiken, South Carolina. NTIS No. SRO-708-1.

Reports progress of a study on the environmental implications of radioactivity released to a Savannah River swamp forest. The specific objectives were to - (1) completely review the literature pertinent to the proposed studies and study areas. (2) Define and mark off the limits of the study area and sampling areas within the overall plot. (3) Compile a list of the most abundant or dominant species in the area and determine the degree to which the various species differ in the concentrations of the radioactive isotopes: CS^{137}, CO^{60}, ZN^{56}. (4) Identify the potential problem species that, because of their migratory habits and value as human food, carry isotopes off the Savannah River plant site. (5) Initiate food chain studies involving the dominant and problem species. (6) Develop a model of the swamp forest to serve as a guide for the design of future studies and the identification of important components of the systems and transfer coefficients between these compartments of the model.

772. Saville, T. 1966. Study of Estuarine Pollution Problems on a Small Unpolluted Estuary and a Small Polluted Estuary in Florida. Univ. Florida Engineer Progress 20(8):Bull. Ser. No. 125. 210 pp.

A three and one-half year study designed to evaluate the ability of an estuary to assimilate waste under natural and controlled conditions. (WE)

773. Schlesinger, W.H. 1978. Community Structure, Dynamics, and Nutrient Cycling in the Okefenokee Cypress Swamp Forest. Ecological Monographs. 48(4):43-65.

774. Schroeder, G. L. 1975. Some Effects of Stocking Fish in Wastewater Treatment Ponds. Water Research 9:591-595.

Oxidation ponds or sewage lagoons often present characteristics of natural water bodies in an extreme state of ecological imbalance. Excess nutrients of the decaying waste give rise to plankton blooms which subsequently die. In such conditions dissolved oxygen concentrations (DO) in the water are often low and the pH depressed. The addition of fish to ponds which twice a week received, per ha, wastes with a 5 day BOD of up to 800 kg (20 C) and 5600 kg solids, reduced plankton and benthic populations, increased the average DO, and raised the pH. All of these changes improve the effectiveness of a waste treatment pond for reducing BOD and removing nutrients from the water. Bacteria concentrations were as much as 15 times lower in treament ponds stocked with fish as compared with unstocked ponds. Lower bacteria concentrations however reduced the rate of loss of COD in the solids of the waste. (AA)

775. Schrouder, J. D. 1974. Forage Production in Municipal Wastewater Treatment Lagoons. Michigan DNR, Fisheries Div., Grand Rapids.

776. Schulze, K.L. 1966. Biological Recovery of Wastewater. J. Water Pollut. Control Fed. 38:1914.

777. Schurr, K., and J. M. Golonbeck. 1974. Calculated Yield of Sewage Lagoon Biomass. A Plan for Production, and Some Problems Inherent in Using Biomass or Lagoon Water for Production of Food and Fiber, pp. 102-110. In Wastewater Use in the Production of Food and Fiber. U. S. Environmental Protection Agency. Ada, OK.

778. Schwartz, H. G., Jr., and B. S. Shin. 1980. Combined Aquaculture Systems for Municipal Wastewater Treatment - an Engineering Assessment, pp. 81-104. In S. C. Reed and R. K. Bastian (eds.), Aquaculture Systems for Wastewater Treatment: An Engineering Assessment. EPA 430/9-80-007. U.S. Environmental Protection Agency, Office of Water Program Operations. Washington, DC.

The purpose of this paper is to assess the current status of combined aquaculture systems developed for municipal wastewater treatment and determine if these concepts are ready for routine use and, if not, what must be done to make them a reality. A combined aquaculture system, or polyculture system, is defined for this paper as one in which major wastewater treatment work is carried out by several different levels of aquatic organisms. It includes wastewater treatment ponds with a combination of components such as mechanical elements, aquatic plants, invertebrates, and fish.

779. Schwegler, B.R., Jr. 1977. Effects of Secondary Effluent on the Plant and Soil Components of a Northern Wetland Ecosystem, pp. 312. In: R.H. Kadlec, D.L. Tilton, and J.A. Kadlec (eds.), Feasibility of Utilization of Wetland Ecosystems for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent, Semi-Annual Report No. 5. Univ. of Michigan, Ann Arbor.

Continuous flow bioassay chambers were used to determine the effects of sewage effluent on the growth rates and nutrient concentrations of filamentous algae in a northern Michigan wetland. Bioassay growth rates were

2656 mg dry wt. m^{-2} day $^{-1}$ at the site of effluent addition and 85 mg dry wt. m^{-2} day^{-1} at the control site. Phosphorus concentrations were significantly higher in algae grown at the pipeline site (0.47%) than in algae grown at the control site (0.12%). These differences in growth rates and phosphorus concentrations represent 0.96 g m^{-2} P in the algae at the effluent addition site and 0.006 g m^{-2} P in the algae in the control site. Calculations for examining uptake rates are presented and discussed. Suspended sediments limited the photic zone to the upper 3-5 cm of the water column. (AA)

780. Schwegler, B. R., Jr. 1978. Effects of Sewage Effluent on Algal Dynamics of a Northern Michigan Wetland. Master's Thesis. Univ. of Michigan, Ann Arbor.

781. Schwegler, B. R., and C. J. Richardson. 1977. Effects of Nutrient Additions on Algae in a Central Michigan Wetland. Bulletin of the Ecological Society of America. Houghton Lake, MI.

782. Sea Pines Public Service District. 1981. Wastewater Management Study: Effluent Reuse and Disposal. Volume 1 Technical Report. Hilton Head Island, SC.

Among other methods of effluent disposal, an experimental wetlands application system will be constructed to evaluate the potential for this method of effluent disposal. A 4' by 10' unlined ditch will be excavated across the wetland. Effluent will be discharged to the ditch via small diffuse pipes at 100' spacing.

783. Searsbrook, E., and D. W. Davis. 1971. Effect of Sewage Effluent on Growth of Five Vascular Aquatic Species. Hyacinth Control J. 9:26.

784. Seidel, K. 1966. Purification of Water by Higher Plants. Naturwissen-Schaften (German) 12:289-297.

785. Seidel, K. 1971a. Wirkung Hoherer Pflanzen Auf Pathogene Keime in Gewassern. Naturwissenschaften 58(4):150-151.

786. Seidel, K. 1971b. Macrophytes as Functional Elements in the Environment of Man. Hydrobiologia 12:121-130.

787. Seidel, K. 1976. Macrophytes and Water Purification, pp. 109-121. *In* J. Tourbier and R. W. Pierson, Jr. (eds.), Biological Control of Water Pollution. Univ. of Pennsylvania Press, Philadelphia.

788. Seidel, K., and R. Kickuth. 1967. Biological Treatment of Phenol-containing Wastewater with Bulrush (*Scirpus lacustris L.*). Wassersirtschaft-Wassertechnik. 17(6):209-210.

789. Sell, M.G. 1977. Modeling the Response of Mangrove Ecosystems to Herbicide Spraying, Hurricane, Nutrient Enrichment, and Economic Development Ph.D. Dissertation Dept. of Env. Engr. Sci. University of Florida, Gainesville. 389 pp.

790. Semkin, R. G., A. W. McLarty, and D. Craig. 1976. A Water Quality Study of Cootes Paradise. Water Resources Assessment, Technical Support Section, Ministry of the Environment, West Central Region. Toronto, Ontario, Canada.

Studies were performed on a deep-water, channelized wetland in Ontario, Canada, that received a wastewater discharge. Nitrogen removal was good. Heavy metals were present in sediment samples collected downstream from the discharge. (EP)

791. Shannon, E. E. et al. 1976. Polychlorinated Biphenyls (PCB's) in Municipal Wastewaters. Research Rept. No. 49, Ministry of the Environment, Ontario, Canada.

792. Shedden, R.D. 1974. The Significance of Biological Denitrification of Nitrate Polluted Ground Waters in the Anaerobic Sediments of Wetlands. Ms. Thesis. Tufts Univ., Newton, Mass.

793. Sheffield, C.W. 1967. Water Hyacinth for Nutrient Removal. Hyacinth Control J. 6:27-30.

794. Shelef, G. 1978. The Combination of Algal and Anaerobic Waste Treatment in a Bioregenerative Farm System. United Nations Univ. Conference on "The State of the Art of Bioconversion or Organic Residues for Rural Communities", Guatemala City, Guatemala, 13-15 Nov. 1978.

795. Shelef, G. et al. 1977. Economic Aspects of Microalgae Production on Sewage. GSF Workshop on Microalgae for Food and Feed - A Status Analysis, Munchen, Oct. 17-18, 1977.

796. Shelef, G. et al. 1980. Algal Mass Production as an Integrated Part of Wastewater Treatment and Reclamation. In: Proc. Int. Symp. Prod. and Use Algal Biom., Shelef and Soeder (eds.), Elsevier, Amsterdam.

797. Shelef, G., R. Moraine, and E. Sandbank. 1977. Physico-Chemical Treatment of Pond Effluents for Unrestricted Agricultural Reuse with Recovery of Algae as Protein Source: Pilot and Field Scale Experiments. Technion-Israel Inst. of Tech., Haifa. Sherman Environmental Engineering Research Center. 17 pp.

Alum flocculation coupled with flotation was found to upgrade stabilization pond effluents to quality permitting reuse for unrestricted irrigation. Removal of phosphate by the alum permits seasonal impoundment of the clarified effluent with minimal eutrophication. The by-product algal sludge can serve as a high quality protein source for poultry and fish, replacing over a quarter of the soymeal in broiler ratios as well as over three-quarters of the fishmeal in carp rations. The combined values of waste disposal, renovated water, and feed protein make the system highly economical. (NT)

1091. Shiaris, M.P. In press.

798. Shih, S.F. 1981. Upland Marsh for Water Quality Control. Journal of the Environmental Engineering Division, Proceedings of the ASCE, 107 (EE4): 861-864.

Although many studies have investigated the use of vascular plants to improve the water quality of fresh water marshes, previous researchers have not emphasized the application of models to determine plant nutrient uptake in marshes. This study used time series analysis to analyze plant nutrient uptake, used the F-test as the statistical criterion to determine the possibility of any component existing in series, and demonstrated the application of time series analysis to interpolate missing data. Since plant nutrient uptake is a function of time, time series analysis can be used to observe the trends, cyclical movement, and residual pattern of a water quality system in marsh areas. Total phosphate data taken at 4 hour intervals over a 5 day period in September was used to demonstrate the application of time series analysis. The Fourier coefficients, amplitude, phase angle, and percent of variance were determined for each harmonic at three sampling sites. The Fourier analysis showed that three harmonics explained over 83 percent of the variance. The amplitudes were much smaller in the marsh than in the slough, confirming the reduction of total phosphate after the water flowed through the marsh zone. Interpolation of missing data based on time series function resulted in somewhat higher values than estimates based on conventional linear function. The F-test for the cyclic function component of the marsh site was significant at the 0.01 level, demonstrating the existence of the cyclic component in the marsh zone system.

799. Shih, S. F., A. C. Federico, J. F. Milleson, and M. Rose. 1979. Sampling Programs for Evaluating Upland Marsh to Improve Water Quality. Transactions of the American Society of Agricultural Engineers 22(4):828-833.

800. Shindala, A. 1972. Nitrogen and Phosphorus Removal from Waste Waters. Part 1. Water & Sewage Works Journ. Jun:66-71.

801. Shore, F., W. Van Zandt, and W. Smith. 1977. Water Hyacinths for Removal of Toxaphene from Water. J. Miss. Acad. Sci., 22(supp.): 17-22.

802. Siccama, T. G., and E. Porter. 1972. Lead in a Connecticut Salt Marsh. Bio Science 22(4): .

The author reports that a salt marsh removes and stores lead from inflowing waters washed from urban pavements.

803. Sickels, F. A., R. L. Simpson, and D. F. Whigham. 1977. Decomposition of Vascular Plants in a Delaware River, Freshwater Tidal Marsh exposed to Sewage Spray Irrigation. Bulletin of the New Jersey Academy of Science 22(2):41-42.

804. Silvo, O. E. J. 1972. Some Experiments on Purification of Wastewaters from Slaughterhouses with Sphagnum Peat, pp. 311-318. In Fourth Int. Peat Congr. Proc., Ontaniemi, Finland.

805. Simmers, J. W., B. L. Folsom, Jr., C. R. Lee, and D. J. Bates. 1981. Field Survey of Heavy Metal Uptake by Naturally Occurring Saltwater and Freshwater Marsh Plants. U.S. Army Engineer Waterways Experiment Station. Environmental Lab Vicksburg, MS. 161 pp.

A natural marsh heavy metal survey was conducted to establish a baseline for comparison to plant concentration and uptake data from contaminated and perturbated sediments. Extensive field sampling of natural marshes was conducted along the east and gulf coasts of the United States, and along the shores of the Great Lakes. *Spartina alterniflora* was collected from the saltwater marshes and *Cyperus* species were collected from the freshwater marsh areas.

Results indicated that, in the saltwater marsh, Mn and Zn concentrations were slightly lower than those previously determined in greenhouse and disposal site studies with contaminated sediments, while the concentrations of the remainder of heavy metals were similar. Calculation of total uptake values indicated that only Cd may be of concern. Cd levels in Cyperus species in naturally occurring marshes were similar to those of a greenhouse flooded (reduced) environment. Fe and Mn were generally present in lower concentration in the natural marsh than in the greenhouse plants grown on contaminated sediment, while the remainder of the heavy metals examined were present in higher concentrations.

This investigation forms the basis for the conclusion that marsh plants grown on contaminated dredged material in a flooded environment do not bioconcentrate excessive or even significantly higher levels of toxic metals than those same plant species in naturally occurring marshes. (AA)

806. Simpson, H. J. 1979. Dredge Spoils and Sewage Sludge in the Trace Metal Budget of Estuarine and Coastal Waters. National Technical Information Service Report PB-295-711. 224 pp.

Human-induced increases in heavy metal and PCB pollution in the Hudson River estuary were monitored. Anthropogenic increases of 3-6 times natural levels were detected for Zn, Cu, and Pb. Measurements indicate that the predominant source of organic pollution in the estuary is sewage. A new technique developed to trace the distribution of cellulose in coastal sediments is described. Management alternatives that could minimize adverse impacts of sewage disposal on the estuary are considered. (EL)

807. Simpson, R. L. 1979. The Effects of Sewage Spray Irrigation in a Freshwater Tidal Wetland. II. Decomposition Studies. Presented at the Annual Meeting of the American Institute of Biological Sciences, held 12-17 August 1979, at Stillwater, OK.

808. Simpson, R. L., and D. F. Whigham. 1978. The Impact of Treated Sewage on Water Quality of a Delaware River Freshwater Tidal Wetland. Paper presented at Annual Meeting American Society of Limnology and Oceanography.

809. Simpson, R.L. and R.E. Good. Fluxes of Heavy Metals in Freshwater Wetlands Rutgers Univ., NJ Manuscript.

The project objectives are to identify specific compartments of heavy metal (especially Pb, Cd, Zn) accumulation in freshwater tidal wetlands, monitor fluxes among these compartments, and determine the upper thresholds of these compartments for heavy metal content. Phase one of the study is to identify sites of heavy metal accumulation in the study area, determine seasonal changes in heavy metal concentrations in the plants, sediments, and detritus, and the role of water in moving heavy metals to and from the sediments. Phase two of the study will determine the fate of heavy metals added to the wetland experimentally.

The results of this study should identify the way in which freshwater tidal wetlands act as "sinks" for heavy metals and the role these wetlands play in immobilizing these pollutants.

810. Simpson, R. L., D. F. Whigham, and R. Walker. 1978. Seasonal Patterns of Nutrient Movement in a Freshwater Tidal Marsh, pp. 243-258. In R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, New York.

The distribution and movement of dissolved O_2, CO_2, NO_3-N, NH_3-N and PO_4-P in the surface waters of a freshwater tidal marsh were studied. Tidal action, particularly periodic inundation and flushing, resulted in distinctly different patterns of nutrient distribution in the major wetland habitats. Inorganic N and PO_4-P were accumulated in the marsh during summer with emergent vegetation appearing to play an important role in the uptake and retention of nutrients. Although evidence is accumulating that some N and P may be translocated into belowground parts by several perennial macrophytes, most is rapidly leached after death of vascular plants with up to 80% of the total N and even more of the P lost within 1 month. In pond-like areas where filamentous algal blooms develop following the fall dieback of vascular plants, inorganic N and PO_4-P levels remain depressed through the winter and spring. On the basis of presently available evidence, it appears almost all habitats of freshwater tidal marshes may be sinks for inorganic N and PO_4-P during the vascular plant growing season and that certain habitats may continually function as sinks. (AA)

811. Simpson, R.L., D.F. Whigham, and F. Sickels. 1979. The Effect of Sewage Spray Irrigation in a Freshwater Tidal Wetland II. Decomposition Studies. Paper Presented at Annual Meeting Ecological Society of America.

812. Sinclair, L.R. and R.B. Forbes, 1980. Nutrient Removal from Drainage Waters with Systems Containing Aquatic Macrophytes. Transactions of the ASAE. 23(5):1189-1194.

Water quality was measured at the inflow and outflow of three treatment systems to determine their effectiveness in removing nutrients from agricultural drainage water. The study was adjacent to Lake Apopka, Florida, which has undergone eutrophication during the past 50 years from nutrients added by drainage water from muck farming. A natural swamp was not very effective in improving water quality. Turbidity, sulfate, pH, and nitrates were slightly reduced, and alkalinity, ammonia, phosphate, tannin-lignin, carbon dioxide, and temperature increased slightly. Oxygen concentration decreased significantly. An anaerobic system, floating water hyacinths planted in a 16.2 hectare reservoir, improved water quality slightly through the growing season. Nitrates, oxygen, phosphates, and sulfate decreased; other changes were not statistically significant. This method was most effective of the three in nitrate removal. After the water hyacinths started to decay, water quality degenerated. A 0.4 hectare recycle reservoir containing Najus, submerged plants, removed nutrients very effectively. In this aerobic process, alkalinity, ammonia, carbon dioxide, phosphate, tannin-lignin, turbidity, and sulfate decreased significantly, and oxygen and pH increased significantly. This system was effective in winter. The author speculated that a combination of naiad and hyacinth systems might produce improved results. The possibility of using emergent plants such as cattails was also mentioned.

813. Sinha, S.N., and L.P. Sinha. 1969. Studies on Use of Water Hyacinth Culture in Oxidation Ponds Treating Digested Sugar Wastes and Effluent of Septic Tank. Environmental Health 11:197-207.

814. Slaughter, R., and I. Wile. 1979. Natural and Artificial Marshes for Sewage Treatment in Ontario. In: J.C. Sutherland, and R.H. Kadlec (eds.), Wetlands Utilization for Management of Community Wastewater. Abstracts of a Conference held 10-12 July 1979 at Higgins Lake, MI.

To determine potential of wetlands for year-round sewage treatment in Ontario, an experimental study using both a natural and artificial wetland will commence in 1979. The study will attempt to define the degree of pretreatment of the waste required prior to discharge to the wetlands, maximum loading rates and required retention periods to establish optimal operational limits for the systems. Also operational costs and land requirements for wetland treatment systems will be assessed.

The artificial marsh system will consist of four separate 980 m^2 cells, two of which will be channelled to permit harvesting of the cattails, Typha spp. Two of the cells will receive raw aerated sewage and the remaining two will be treated with sewage lagoon effluent. The operating range will provide for retention periods between 2 and 10 days and areal loading rates between 1 and 10 cm/day. An additional marsh/pond/channelled marsh system will be operated in series and treated with lagoon effluent. The marsh cell of this system will operate at depths of 5 to 30 cm and 1 to 4 day retention periods. The pond will be maintained at a 90 cm depth with a retention time of 2 to 9 days and the channelled marsh at 5 to 30 cm depths with 0.5 to 2 day retention periods. A small 30 m^2 cell with an impermeable lining will be used for evapotranspiration studies. Construction of the facility is scheduled to commence in July 1979, adjacent to the town of Listowel sewage treatment lagoons.

In addition, a 1400 m^2 plot, adjacent to the town of Bradford sewage treatment plant has been fully instrumented to permit detailed measurements of its water balance. The site is densely populated by both Typha latifolia L. and Typha angustifolia L. Background nutrient budgets for the plot will be monitored for two years prior to the addition of partially treated wastes from the sewage treatment plant. (AA)

815. Sloan, L. 1971. Sewage Oyster-Farm. Technology Review 73(6):72.

816. Sloey, W. E., F. L. Spangler, C. W. Fetter, Jr. 1976. Productivity and Phosphorus Distribution in Natural and Artificial Marshes in Wisconsin. Aquatic Ecology Newsletter 9:20-21.

817. Sloey, W. E., F. L. Spangler, and C. W. Fetter, Jr. 1978. Management of Freshwater Wetlands for Nutrient Assimilation, pp. 321-340. *In* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, New York.

Nutrient transformation processes such as sorption, coprecipitation, active uptake, nitrification and denitrification remove P and N from the free-flowing water of a wetland and transfer them to the substrate and biota for storage. Advantage is being taken of these processes by using wetlands to treat sewage in Germany, Holland, Finland, and other European countries. In the U.S.A., experimental application of cultural water (wastewater) to peatlands in Michigan, tidal marshes in Louisiana and New Jersey, cattail marshes in Wisconsin, cypress domes and sawgrass in Florida and many more have shown promising results. Denitrification may ~~remove up to 3.5 kg N/ha/day and as~~ much as 20 g P/m^2 may be detained a growing season. Natural release of nutrients between growing seasons, however, either restricts application periods, or demands management of the wetland systems to regulate such releases. The most obvious management tool, plant harvesting, removes only a few grams of P per square metre per year which is usually 20% of that detained. Most of the remainder is in the substrate-microbial compartment and is subject to between-season washout.

Other management techniques used and proposed, such as dikes, drains, and intermittent application, relate to manipulating the hydraulics of the system to optimize conditions for assimilative biogeochemical processes and to prevent washout from reaching surface waters. Chemical treatment to reduce the surplus of P has also been considered. Management options for a specific wetland will depend to a large extent upon that particular hydrologic regime. Riverine systems have different hydraulic patterns than lacustrine or palustrine systems. Flow-through systems cannot be managed like influent or seepage systems. Already, changes in the biota of some experimentally treated wetlands indicate undesirable disturbances of these valuable natural resources. Caution in widespread use of natural wetlands to treat waste at this time is advised and careful monitoring of all biotic communities in experimental programs is essential. Artificial marshes and peat filters offer feasible alternatives to other treatment methods for small systems and do not endanger natural wetlands. (AA)

818. Small, E. and J.D. Gaynor. 1975. Comparative Concentrations of Twelve Elements in Substrates and Leaves of *Scirpus validus* and Other Aquatic Plant Species in a Sewage Lagoon in Unpolluted Habitats. The Canadian Field Naturalist, 88, 1975, pp. 44-45.

Concentrations of 12 elements were examined in vegetation and associated soils and water of 12 rooted aquatic plant species growing in the lagoon of a sewage treatment plant, and elsewhere in unpolluted habitats. Near the point of discharge of effluent into the lagoon, the substrate accumulated sludge, with very high concentrations of Cl, Zn, and Cu, and also notably high concentrations of P, Fe, and Ca. The only rooted aquatic plant species successfully colonizing this area was Scirpus validus which accumulated significantly higher concentrations in the leaves of P, Fe, Cl, N, Na, and Mg compared with the same species in nonsludge areas of the lagoon, and in unpolluted habitats. Eleven additional aquatic plant species were found in the lagoon, rooted in sandy sediment adjacent to the sludge area. These species appeared excluded from the sludge area. Concentrations of the 12 elements examined in substrates and leaves of these species growing just outside the sludge area did not differ notably in comparison with concentrations in unpolluted habitats. (AA)

819. Small, M.M. 1967. Fresh Water from Sewage in Long Island. Brookhaven National Lab, Upton, NY. NTIS No. BNL-21371. April, 1967. 16 p.

Sewage and cesspool contents were used to recharge groundwater in studies at the Brookhaven National Laboratory in Upton, New York. The wastewater purification system was a sloping grass meadow draining into a planted marsh and eventually into a fish-stocked pond. The sewage was applied to the meadow where it permeated the soil and plant roots. The wastewater passed through the marsh soils, plant stalks, and root before flowing into the pond. Overflow from the pond was usable as potable water. The same degree of purification could be attained by a marsh/pond system where meadowland is not available and there is a high population density. Both systems were completely lined so the wastewater could not percolate into the groundwater before purification. The system produced no sludge or odor. The marsh/pond sewage treatment system costs an estimated $1,440,000 compared to $640,000,000 for a municipal sewage treatment plant.

820. Small, M.M. 1975a. Brookhaven's Two Sewage Treatment Systems. Compost Science 16(5):7-10.

Now operating at Brookhaven National Lab on Long Island, NY, are two novel sewage treatment systems, each of which processes 10,000 gpd domestic sewage and returns drinkable water to the groundwater supply. Neither system produces any sludge. The meadow-marsh-pond system and the marsh-pond system, which are in competition to determine the least expensive to build and operate, are described. (EL)

821. Small, M. M. 1975b. Meadow/Marsh Systems as Sewage Treatment Plants. Brookhaven National Laboratory, Upton, NY. 39 pp. (NTIS Rept. BNL-20757).

All parameters of the marsh/pond and the meadow/marsh/pond systems that have been measured to date indicate that both systems produce water suitable for groundwater recharge or other reuse without a public health hazard. This discharged water can be made to satisfy both effuent and drinking water standards. Both systems can be recommended for use as sewage treatment plants, water producers, and farms for sewage loads from 10,000-1,000,000 gpd. Land availability and its terrain will be principal determinants in choosing between the systems for a particular application. (EL)

822. Small, M. M. 1976a. Marsh/Pond System. Brookhaven National Laboratory, Upton, NY. 28 pp.

Data from the first year of operation of the Marsh/Pond semi-works at Brookhaven National Laboratory are reported. Sewage is first aerated, then passed through a marsh, then through a pond, and finally, is spread on a forest floor to recharge groundwater supplies. Since the system is still under study, detailed conclusions would be premature; however, it was observed that a Marsh/Pond system will convert weak sewage to water suitable for recharge through a vegetated sandy loam.

823. Small, M. M. 1976b. Marsh/pond Sewage Treatment Plants, pp. 197-214. In D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

At Brookhaven National Laboratory today there is operating a 10,000 gallon per day sewage treatment system that consists only of a marsh and a pond. The influent to this system is raw sewage blended with septage and sludge. The effluent is potable water. The system is odor, rodent, fly, and mosquito free. It produces no sludge nor airblown particles. It is a pleasant site to have next door, complete with fish, birds, and wildlife. It produces a useful annual crop which is salable. This project is the prototype of similar systems that are proposed for communities of up to 10,000 people. They can be built at a cost of about 60¢/gal day and operated at less than one man year expense. (AA)

824. Small, M. M. 1976c. Data Report, Marsh/Pond System. Preliminary Rept. No. 50600 to the U.S. Energy Research and Development Administration. Brookhaven National Laboratory, Upton, NY. 28 pp.

This report summarized data compiled after one year's operation of an experimental marsh/pond system constructed at Brookhaven National Laboratory, Upton, New York, in 1973. This facility was one of a number of facilities used as prototypes to develop natural systems for the renovation of wastewater. Because the system was under study at the time this report was written, no detailed conclusions were drawn except the observation that a marsh/pond system will convert weak sewage into water that is suitable for recharge through a vegetated sandy loam. (EP)

825. Small, M. M. 1977. Natural Sewage Recycling Systems. Rept. to the U.S. Energy Research and Development Administration. Brookhaven National Laboratory, Upton, NY. 37 pp.

This paper reviews the work done at Brookhaven National Lab, in the development of natural systems which produce potable water from sewage. Experiments with two prototype systems, a marsh/pond and meadow/marsh/pond system, are described, and performance data are presented in detail for the marsh/pond system. Empirical interpretation of results achieved to date are suggested for the use and design of marsh/ponds as natural sewage recycling systems. (WE)

826. Small, M.M., 1978a. Artificial Wetlands as Non-point Source Wastewater Treatment Systems. In: Drew, M.A. (ed.), Environmental Quality Through Wetlands Utilization. Proceedings of a Symposium held 28 February - 2 March 1978 at Tallahassee, FL, p. 171-181.

A comparison of nutrient data from the Taylor Creek, Florida farm wastewater drains with characteristics of effluent from the Brookhaven, New York lowland system models shows about the same concentration on NO_3-N and and PO_4-P in the discharges from both systems. An analysis of each system indicates that both operate at a higher input rate of phosphates than the natural biological communities are removing. In the case of the Brookhaven models, the 2 ppm of PO_4-P in the effluent is insignificant; in the case of drains leaching to Lake Okeechobee, the 2 ppm is excessive.

Over four years experimentation with the meadow/marsh/pond model indicates that modifications of this design, with care in operation, will remove both inorganic nitrogen and phosphorus to levels which no longer constitute a threat to the Lake. If it is true that the annual dump of PO_4 into the Lake is contributed principally by runoff from the farms, that dump can be eliminated by detaining the runoff at each farm by a marsh/pond.

For low-cost, low-energy detention systems for this purpose, it is suggested that the Demonstration Project consider, at each farm, a marsh/pond combination which is designed to remove some water by evaporation, a lot of nitrogen by denitrification, and the major portion of available phosphate by the harvest and removal from the basin of indigenous aquatic weeds.

This paper develops a module for such a lowland nutrient removal system. Construction costs depend on size but will be below $2800 per acre of farm. Operating costs are under 18¢/1000 gallons. (AA)

827. Small, M. M. 1978b. Wetlands Wastewater Treatment Systems, pp. 141-149. In H. L. McKim (ed.), State of Knowledge in Land Treatment of Wastewater. Volume 2. Proceedings of an International Symposium Sponsored by the U.S. Army Corps of Engineers, held 20-25 August, 1978.

Two artificial wetlands sewage reclamation systems are examined from an engineering viewpoint. The systems appear to be technically superior to conventional secondary treatment plants and the efficiency of such systems can be compared to that of advanced wastewater treatment plants. Estimated construction, operation, and maintenance costs of artificial wetlands are far less than equivalent costs are for either conventional or advanced treatment plants in the 38-3800 m^3/day flow range. Energy consumed in artificial wetlands construction is estimated to be a small fraction of the total energy required to build a conventional or advanced treatment plant. Design constraints that are necessary to gain the sewage reclamation are presented. (EL)

828. Small, M.M. 1979. Marsh/pond Sewage Treatment Plants II. In: J.C. Sutherland and R.H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a Conference held 10-12 July 1979 at Higgins Lake, MI.

A general description of artificial wetlands, built and operated at Brookhaven National Laboratory for the treatment of sewage, was presented at the Freshwater Wetlands and Sewage Effluent Disposal Conference, May 10-11, 1976 at the University of Michigan. In May, 1976 an artificial Marsh/Pond and an artificial Meadow/Marsh/Pond had been operated as continuously on-line treatment systems for about 9 months and some preliminary observations were reported - some prescient - others dead wrong. This is an update three years later.

The net conclusion is that artificial Marsh/Ponds work. They make an attractive wetlands which can be constructed almost anywhere. They will not dump raw sewage if overloaded, will generate no sludge for separate disposal and do not produce objectionable odors, vermin or disease vectors. Less than 20 acres of land is sufficient to treat 1 MGD of normal domestic sewage in a Marsh/Pond which will cost about $1 million to build. They are an energy bargain for today. (AA)

829. Small, M., and C. Wurm. 1977. Meadow/Marsh/Pond System. Data Report to U.S. Energy Research and Development Administration. Brookhaven National Laboratory, Upton, NY. 33 pp.

This report summarizes 13 months' operating data, August 1975-August 1976, from the Meadow/Marsh/Pond system, one of two natural sewage-treatment systems constructed at Brookhaven National Laboratory. These systems are free of disease vectors, aerosols, and objectionable odors. The Meadow/Marsh/Pond system appears superior to the Marsh/Pond system for renovating blends of septage and weak sewage to groundwater recharge quality. The only conclusion offered at the present time is that the system will produce potable water from raw sewage following recharge of pond effluent through a vegetated sandy soil.

830. Smith, D.W. 1980. Water Reclamation and Reuse. J. Water Pollut. Control Fed. (Literature Review Issue) 52(6):1242-1284.

A review of recent (1978-1979) literature on water reclamation and use highlights the Water Reuse Symposium held March 25-30, 1979, in Washington, D.C., which dealt with water reuse from the research, development, and application viewpoints. In addition to a summary of general papers, the article discusses recent developments in water resources planning (models, options in wastewater reuse).

831. Smith, G. R. 1978. Botulism, Waterfowl and Mud. British Veterinary Journal 134(5):407-411.

832. Smith, L. J., and J. E. Huguenin. 1975. The Economics of Wastewater Aquaculture Systems, pp. 285-293. In I. E. E. E. Conf. Record of Engr. in the Ocean Environment - Ocean '75. San Diego, CA.

833. Smith, R. C. 1975. Hydrogeology of the Experimental Cypress Swamps. Master's Thesis. Department of Geology, Univ. of Florida, Gainesville. 87 p.

834. Smith, W. G., and J. W. Day. 1973. Enrichment of Marsh Habitats with Organic Wastes. Completion Report. Louisiana Water Resources Research Institute. Baton Rouge, LA. 9 pp.

Municipal and industrial wastewater have created local problems, including eutrophication, plant nutrient loss, discharge-induced die-off of algal flora, and changes in chemical and biological character. Among methods used to solve these problems is that of overland runoff, and the project is an attempt to incorporate this method into an estuarine environment. A site in the subtropical coastal marsh at Dulac, Louisiana, home port facility for a menhaden processor, was selected: an artificially enclosed freshwater marsh, totaling about two and one-half square miles. (NT)

835. Smithsonian Science Information Exchange Inc. 1976. Utilization and Removal of Nutrients from Fresh Water by Aquatic Vascular Plants. Research Information Package BA14, Washington, DC.

A review of ongoing research supported by various government agencies concerning aquatic ecosystems and the ability to remove nutrients from fresh water.

Contains details of ongoing research projects (updated at least every 90 days). Available from SSIE, Room 300, 1730 M Street, N.W., Washington, DC.

836. Snider, J. R., and G. W. Wood. 1975. The Effects of Wastewater Irrigation on the Activities and Movements of Songbirds, pp. 20-49. In G.

W. Wood, et al. (ed.), Faunal Response to Spray Irrigation of Chlorinated Sewage Effluents. Publication 87. Institute for Research on Land and Water Resources Research, Pennsylvania State Univ., Philadelphia.

837. Sodd, A. N. 1981. Municipal Solid Waste Disposal in Estuaries and Coastal Marshlands: Project Summary. U. S. Environmental Protection Agency. Municipal Environmental Research Lab. Cincinnati, OH.

See MacGregor et al. (1980) for abstract of this project.

838. Sommers, L. E., C. F. Parker, and G. J. Meyer. 1981. Volatilization, Plant Uptake and Mineralization of Nitrogen in Soils Treated With Sewage Sludge. Tech. Rept. No. 133. Water Resources Research Center, Purdue Univ., Lafayette, IN. (Available as NTIS Rept. PB81-173940).

Field and laboratory experiments were conducted to quantify the amount of ammonia volatilization taking place after application of sewage sludge to the soil surface, evaluate the movement of nitrogen and plant uptake from soils treated with sewage sludge, and determine the potential N mineralization in a wide range of sewage sludges. Volatilization of NH_3-N was found to be dependent upon the method of sludge application, initial soil moisture content and sludge pH. Sorghum plants recovered 7 to 27% of the total sludge N while the recovery of the total N ranged from 8 to 33% considering the N in the soil to a depth of 90 cm. Significant losses of sludge inorganic N occurred within 3 days of application. The amount of mineralizable N in 24 sewage sludges was found to be proportional to the total organic N content. The results of the study demonstrated the need to use a different N mineralization percentage for the the various sludge types. Recognizing the limitation of the study, the recommended N mineralization percentage to use in calculating the appropriate sludge application rate for agronomic crops is 25% for raw and primary sludges, 40% for waste activated sludges, 15% for anaerobically digested sludges and 8% for composted sludges. (WR)

839. Sopper, W. E., and L. T. Kardos (eds.). 1973a. Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Pennsylvania State University Press, University Park, PA.

840. Sopper, W. E., and L. T. Kardos. 1973b. Vegetation Responses to Irrigation with Treated Municipal Wastewater, pp. 271-294. In Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. University Park, Penn. State Univ. Press.

841. Sopper, W.E. 1976. Renovation of Municipal Wastewater for Groundwater Recharge by the Living Filter Method, pp. 269- . In: J. Tourbier, and R.W. Pierson, Jr. (eds.), Biological Control of Water Pollution. Univ. of Pennsylvania Press, Philadelphia.

The idea embodied in this concept is to apply wastewater for direct recharge to the groundwater reservoir. This can be accomplished by controlling application rates and by maintaining normal aerobic conditions within the soil. Under these conditions organic and inorganic constituents in the wastewater are removed and degraded by microorganisms, chemical precipitation, ion exchange, biological transformation, and biological absorption through the root systems of the vegetative cover. The utilization of the vegetative cover as an integral part of the system to complement the microbiological and physiochemical systems in the soil is an essential component of the living filter concept and provides for maximum renovation capacity and durability of the system.

842. Sorber, C.A. and K.J. Guter. 1975. Health and Hygiene Aspects of Spray Irrigation. Amer. J. Publ. Hlth. 65(1):47-51, 1975.

The following conclusions relative to the health and hygiene effects of spray irrigation land disposal of wastewater can be drawn. 1) Many of the detrimental health and hygiene aspects of land disposal should be significantly reduced by proper wastewater pretreatment including secondary treatment, filtration, and complete disinfection. 2) By choosing a land disposal site that has from 5-10 feet of continuous fine soil, biological contamination of groundwater can be avoided. 3) The probability of inhaling pathogenic aerosols near a spray irrigation site may be significant. 4) If ponding results in spray irrigation areas mosquito breeding is enhanced. 5) In areas where land disposal is the first step in a water recycle program, total dissolved solids, sodium, and nitrate buildup in the ground water supply can be a problem.

843. Spangler, F.L., C.W. Fetter, Jr., and W.E. Sloey. 1977. Phosphorus Accumulation-Discharge Cycles in Marshes. Water Resources Bulletin 13(6):1191-1201

Artificial and natural marshes were studied to determine changes in quality of polluted water passing through them. Phosphorus removal ranged from zero to 64%. Removals in the 35% range were common, however. Much of the phosphorus went into sediments and unharvestable plant parts. Harvesting vegetation removed 6% of the phosphorus put into the system. Accumulation of phosphorus during the growing season was about 10 g m^2, much of which was flushed out after the onset of freezing weather. The amount of phosphorus flushed out can be prevented from entering a lake or stream by handling the marsh discharge in one of three ways: irrigate on land, lagoon to recycle later, treat conventionally if facilities are available. (AA)

844. Spangler, F. L., W. E. Sloey, and C. W. Fetter, Jr. 1976a. Artificial and Natural Marshes as Wastewater Treatment Systems in Wisconsin, pp. 215-240. In D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

Artificial marshes were constructed by lining excavations with 20 mil PVC, placing gravel in them, then planting emergent vegetation, especially softstem bulrush (*Scirpus validus*). A control was used. Observations were made on the effect of the artificial marshes, first on secondary, then on primary effluent. A study was also done on water quality improvement by a polluted natural marsh.

It was found that phosphorus removals of 30 - 40% could be expected in both natural and artificial marshes but ranged up to 64%. Removal during the growing season may be negated by loss during winter and spring unless a management technique is developed and applied. Harvesting of plants is not a feasible P removal technique nor does it influence treatment efficiency. In the artificial system most of the P (75%) taken out of the wastewater went into the gravel and only about 5% went into harvestable tissue. Most of the purification processes (i.e., BOD removal and nutrient retention) appear to be carried out in the substrate system rather than by the vascular plants.

Highest BOD removals were 91% and 77% for secondary and primary effluent respectively. Retention time did not seem to be critical to BOD removal over the 5-hour to 10-day range for secondary effluent. Effluents with BODs of 5 - 15 mg/l were produced by the artificial marshes in spite of loss of up to 45% of the water by evapotranspiration.

Waste treatment employing emergent vegetation is probably not as energy intensive as traditional methods. Winter application is not thought to be possible in northern latitudes. (AA)

845. Spangler, F., W. Sloey, C.W. Fetter. 1976b. Experimental Use of Emergent Vegetation for the Biological Treatment of Municipal Wastewater in Wisconsin, pp. 161-171. In: J. Tourbier and R.W. Pierson (eds.), Biological Control of Water Pollution.

Native Wisconsin marsh plants were assessed for their ability to provide secondary or tertiary sewage treatment. A 258-ha natural cattail marsh that receives both municipal and industrial waste was investigated; a striking water quality improvement due to movement through the marsh was recorded relative to BOD, COD, O-PO_4, total-P, coliform bacteria, and turbidity. The highest concentrations of nutrients were found to occur in young plant tissue of emergent species; therefore the effects of harvesting were investigated. *Scirpus acutus* (hardstem bullrush) and *S. validus* (softstem bullrush) recovered well post harvest while cattails (*Typha spp.*) did not. Additionally most P was associated with the root rhizomes, and little was harvested in the shoots. (AA)

846. Spangler, F.L., W.E. Sloey, and C.W. Fetter. 1976c. Wastewater Treatment by Natural and Artificial Marshes. EPA Technology Series Rpt. No. EPA-600/2-76-207. September. NTIS No. PB-259 992. 182 p.

The uses of artificial and natural marshes as purifiers of municipal treatment plant effluent was investigated at various sites in Wisconsin. Harvesting plants was not a practical phosphorus removal technique as only a small portion of the phosphorus retained by a marsh system is incorporated into harvestable plant tissue, and then only in summer. The level of water quality improvement attained suggests that the process may be acceptable for polishing effluent from septic tanks of single or small clusters of buildings. Marshes remove phosphorus during the growing season but release it at other times, thus acting as buffers which may be managed to advantage. The natural marsh was moderately effective in removing phosphorus during the growing season but the annual phosphorus output was about equal to the input. Average concentrations of orthophosphate, total phosphorus, conductivity, and total solids were reduced by 13% or less by passage through some 1900 m of Brillion Marsh. The phosphorus concentration in water draining from the marsh ranged from a low of 0.43 mg/l in September to a high of 11.85 mg/l in July, and did not follow any discernable pattern related either to temperature, rainfall or season. Reduction of most parameters did not vary when primary or secondary effluent was treated by a marsh.

847. Spehar, R.L., A.E. Lemke, Q.H. Pickering, T.H. Roush, R.C. Russo, and J.D. Yount. 1981. Effects of Pollution on Freshwater Fish. J. Water Pollut. Control Fed. 53(6): 1028-1075.

848. Spoon, D. 1976. Survey, Ecology, and Systematics of the Upper Potomac Estuary Biota: Aufwuchs Microfauna, Phase II. Rept. No. 8. Washington Technical Inst. Water Resources Research Center, Washington, DC.

Two model rivers, representing Potomac River sites at Haines Point, Blue Plains Sand Piscataway Creek connected to a common reservoir containing upriver water, were studied. Each model consisted of four 24-gallon aquaria. In one model at aquarium 2, frozen sewage was added, and in the other, dechlorinated tap water was added. Four attempts to duplicate the May 1974 fishkill, which took place when river to sewage flow ratio was 20:1, failed: negative results were obtained with aquaria conditions representing river to sewage flow ratios of 20:1, 5:1, 1:1, and 4:4. It was concluded that the fishkill was caused by a toxin in the sewage and not a heat shock or the river model closely approximated those at Potomac River sites at the same temperature. Other studies were done on a 50,000-gallon pilot activated sludge plant before and after hydrogen peroxide treatment of a bulking condition. A new method for counting and studying the activated sludge community was devised using thin plastic film (Handiwrap) coverslips with plastic slides. (NT)

849. Stahl, J. B., and D. S. May. 1967. Microstratification in Waste-treatment Ponds. J. of Water Pollut. Control Fed., 39:72-88.

A study of stratification of temperature and dissolved oxygen content in a small pond receiving wastes that had undergone primary treatment showed that sharp stratification of these properties almost always is present. At a depth of less than two centimeters, only one percent of the surface light remained. Only on heavily overcast, windy days was stratification absent. On calm, clear days, temperature dropped as much as 20°C in 50 cm and oxygen dropped from 300 percent saturation at the surface to 3 percent at 5 cm. These effects were more extreme than those reported for other ponds, few of which, however, were waste treatment facilities. (AA)

850. Stanley Consultants. 1977. New Orleans-Baton Rouge Metropolitan Area, Louisiana, Water Resources Study. Wastewater Treatment by Marsh Application Work Report. Submitted to U.S. Corps of Engineers, New Orleans District. Atlanta, GA. 147 pp.

The potential for using study area marshes for disposal of secondarily treated municipal effluent is discussed and an overview is given of methodologies utilized at 18 sites in the United States. Brief descriptions of the dominant vegetation, type of studies being conducted, and results accumulated at each site are included. Three coastal marshlands in the delta region of the Mississippi River are discussed in greater detail. Specific characteristics such as climate, hydrology, water quality, vegetation, sediments, and limitations to marsh availability are described for the study sites. Mechanisms in natural marshes and the limitations of wastewater application to marshes also are addressed. Based on data gathered in experimental marsh treatment systems, loadings and general criteria were established as guidelines to be used in treatment of marshes. In cases where there was a lack of available data, criteria were chosen arbitrarily. (EP)

851. Stanley, N.E.T.L. Thurow, B.F. Russell, and J.F. Sullivan. 1980. Geothermal Wetlands: An Annotatd Bibliography of Pertinent Literature. Idaho National Engineering Laboratory. U.S. Dept. of Energy. Idaho Falls.

Literature providing information on natural and artificially created wetlands were reviewed. The objective was to gather pertinent data that could be extrapolated to geothermal wetlands. Applicable studies are presented in the form of an annotated bibliography. Emphasis was placed on 1) the characterization of water quality requirements; 2) tolerance limits of wetland flora and fauna; and 3) the potential effectiveness of aquatic vegetation at bioaccumulating solutes inherent in most geothermal waters. (AA)

852. Stanlick, H.T. 1976. Treatment of Secondary Effluent Using a Peat Bed, pp. 257-268. In: D.L. Tilton, R.H. Kadlec, and C.J. Richardson (eds.), Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

The use of a peat bed for systems that operate during the growing season should give an effluent that will meet most if not all discharge requirements. If properly designed and installed, the bed should produce an effluent with no fecal coliform, and little total coliform, without any special disinfection facilities; BOD_5 and suspended solids of approximately 5 mg/l; and nitrogen of less than 10 mg/l. Design life is expected to be 5 to 10 years. With the test results we have, we expect the bed life to be close to ten years. After three years, the treatment efficiency has not deteriorated but in fact has increased.

This type of system can be used to disinfect an effluent and improve the quality all year if you do not have stringent requirements on phosphorus and nitrogen. It is ideal for camps and resorts due to the little operation and maintenance needed.

853. Stearns, F. 1978. Management Potential Summary and Recommendations. pp. 357-363. In: R.E. Good, D.F. Whigham and R.L. Simpson (eds.), Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, New York.

Wetland management goals fall in three areas: environmental protection, recreation and aesthetics, and production of renewable resources. Most wetland management, however, is oriented to several goals and most wetlands serve multiple uses. Several general conclusions concerning wetland management can be made at this time: management decisions should complement natural wetland functions whenever possible. Wastewater should not be applied to natural wetlands, other than experimentally, until more is known about long-term effects. The rate of wetland conversion should be slowed until more is known about wetland functions. Management should hold to a minimum those factors which degrade marsh structure and function. In creating wetlands, one should remember that plant species differ in their vulnerability to stresses. In modifying wetlands, attempt to avoid disturbances. Natural perturbations may occur and management techniques successful at one point in the climatic cycle may not be applicable at other times.

854. Stephenson, M., G. Turner, P. Pope, A. Knight, and G. Tchobanoglous. 1980. The Use and Potential of Aquatic Species for Wastewater Treatment. Appendix A. The Environmental Requirements of Aquatic Plants. Publication No. 65. California State Water Resources Control Board. Sacramento, CA. 380 pp.

855. Steward, K.K. 1970. Nutrient Removal Capacity of Various Aquatic Plants. Hyacinth Control Journal 8:34-35.

856. Steward K.K., and W.H. Ornes. 1973. Assessing the Capability of the Everglades Marsh Environment for Renovating Wastewater. Final Rept. Agricultural Research Service, Fort Lauderdale, FL. 28 pp.

Everglades vegetation was enriched with simulated effluents in order to determine the feasibility of recycling wastewater through the marshes.

Weekly application of nutrients increased assimilation of nutrients by the plants but did not increase growth. This indicated that growth was not limited by lack of nutrients. Only 12% of the applied nutrients were assimilated into the vegetation. Of the amount remaining, 3% was used to produce algal blooms, 43% settled to the bottom, 5% remained dissolved in the water and 37% was unaccounted for. The dense algal blooms, which were maintained throughout the experiment, were believed to have been responsible for the disappearance of several floral components of the ecosystem. Because of the low capacity for nutrient assimilation, and because of potential alterations in species composition, it appeared unlikely that the marsh system could be used to renovate wastewater. (NT)

857. Steward, K. K., and W. H. Ornes. 1975. Assessing a Marsh Environment for Wastewater Renovation. J. Water Pollut. Control Fed. 47(7): 1880-1891.

The authors measured the response of vegetation in the Everglades to enrichment with N and P. Increases in plant tissue nutrient levels, but no changes in growth, were observed after a single application. A dense algal bloom was produced 4-7 weeks after the start of continuous weekly application, which eliminated natural periphyton and Utricularia communities. Based on water, sediment, and tissue nutrient levels, the researchers concluded that sawgrass had limited ability to remove nutrients and that the assimilative capacity of the marsh was exceeded at less than the application level of 2.5 kilograms of P per hectare. (EP)

858. Stewart, E. A., III. 1979. Utilization of Water Hyacinths for Control of Nutrients in Domestic Wastewater - Lakeland, Florida, pp. 273-293. In R. K. Bastian and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. U. S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC.

The use of water hyacinths (Eichhornia crassipes) for removal of nutrients and solids during a demonstration project in Lakeland, Florida indicates that removals are as a result of more than hyacinth uptake. Therefore, if design of a hyacinth system is based upon the uptake and growth kinetics of the plants during cool weather periods, it appears that an ample safety margin can be maintained. The hyacinth growth rates were found to be similar to those found in other studies. A first order design equation based upon the Monod concept using total nitrogen as the limiting nutrient is presented. Other aspects of the hyacinth system such as harvesting, crop processing, and marketing have been investigated, but are still in need of additional field work before maximum effectiveness is realized. (AA)

859. Stewart, W. C., and S. A. Serfling. 1979. The Solar AquaCell System for Primary, Secondary, or Advanced Treatment of Wastewaters, pp. 377-412.

In R. K. Bastian and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. U. S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC.

The Solar AquaCell process is an aquaculturally derived wastewater treatment system which integrates proven wastewater treatment elements to allow greater process control, higher quality effluent, and reduced land area as compared to conventional wastewater lagoons. Three AquaCell pond systems, anaerobic, faculative, and aerobic, all containing high surface area bio-film devices, can be used in series to achieve primary, secondary, and/or advanced treatment, respectively. Three years of pilot scale demonstrations have shown that conservative design practices can be used while also achieving reduced construction, operation and maintenance costs, minimal solids handling, low energy demand, and low operator skill requirements. The use of a multiple series of controlled cells allows a high degree of design and operational flexibility for meeting various effluent quality objectives. The City of Hercules' Solar AquaCell Treatment System (California) is also described. (AA)

860. Stora, G. 1976. Effects of a Freshwater Effluent on the Development of Benthic Communities in a Marine Lagoon. Bull. Ecol. 7(3):275-282. In French).

Since 1966, after installation of the Saint-Chamas hydroelectric plant, the Etang de Berre, (France), has received freshwaters of the Durance Channel. This important freshwater inflow representing approximately 4 times the volume of the lagoon during a year has considerably decreased the water salinity. Studies were made in 1965, 1970 and 1972 to follow the evolution of the benthic populations of the Etang de Berre. Characterized by typical marine populations in 1964 (bivalves, polychaetes), the studies in 1970 show a general degradation of the lagoon populations without substitution of benthic marine population by a brackish population. However, in 1972 the benthic populations were replaced on the littoral coast by a characteristic brackish benthic population.

861. Stout, J. P., A. A. de la Cruz, and C. T. Hackney. 1980. Effects of Harvesting in the Annual Net Above-ground Primary Productivity of Selected Gulf Coast Marsh Plants, pp. 213-222. In V. S. Kennedy (ed.), Estuarine Perspectives. Academic Press, Inc., New York.

862. Stowell, R., G. Tchobanoglous, J. Colt, and A. Knight. 1979. The Use of Aquatic Plants and Animals for the Treatment of Wastewater. Unpublished Paper. Dept. Civil Engineering, Univ. of Davis, CA. 24 pp.

863. Stowell, R., R. Ludwig, J. Colt, and G. Tchobanoglous. 1980. Toward the Rational Design of Aquatic Treatment Systems. Presented at the

American Society of Civil Engineers Spring Convention, Portland, OR, April 14-18, 1980. 59 pp.

The term "aquatic treatment" is defined as wastewater treatment in either natural or man-made wetlands. A summary of the mechanisms involved in the removal of wastewater contaminants (including BOD, solids, N, P, heavy metals, refractory organic compounds, and bacteria and viruses) is included in the paper. Effective use of charts and tables make the concepts easy to follow. The following aquatic system design concepts are presented in the paper:

- Aquatic Processing Unit (APU): an assemblage of plants (and possibly animals) grouped together to achieve specific wastewater treatment objectives
- Aquatic plants and animals for use in aquatic treatment systems
- Climatic influences
- Environmental factors
- Wastewater characteristics
- Process reliability, upsets and recovery
- Resources recovery

The authors also present a guide and checklist for the design of aquatic systems. They conclude that more information is needed to establish fully rational design criteria for aquatic treatment systems. A bibliography of recommended literature also is included. (EP)

864. Strange, J. R. 1976. Effects of High Levels of Inorganic Phosphate on Aquatic Organisms in Phosphate-Rich Environments. P. B. No. 263-390. Environmental Resources Center. Georgia Institute of Technology. Atlanta, GA.

865. Straub, P., and D.M. Post. 1977. Rates of Growth and Nutrient Concentration of Trees in Cypress Domes. Pages 271-318. In: H.T. Odum and K.C. Ewel (eds.), Cypress Wetlands for Water Management, Recycling and Conservation. 45th Annual Report to the National Science Foundation.

866. Struble, J. E. 1977. Nitrification, Denitrification, and Sedimentation Rates in Cypress Ponds Receiving Secondary Treated Sewage Effluent. Master's Thesis. Dept. of Soil Science, Univ. of Florida, Gainesville. 93 p.

867. Suffern, J. S., M. Adams, B. G. Blalock, C. C. Coutant, and C. A. Guthrie. 1978. Growth of Monosex Hybrid *Tilapia* in the Laboratory and Sewage Oxidation Ponds. Presented at meetings of the World Mariculture Society, Atlanta, GA, 3 Jan. 1978. 18 pp.

Studies were conducted to evaluate the potential of monosex hybrid *Tilapia* (female *T. mossambica* x male *T. hornorum*) in waste-heat polyculture systems. The optimum growth temperature for this hybrid was found to be 32°C in laboratory experiments. Experiments in sewage pond cage culture in the temperature range of 23 to 33°C at stocking densities of approximately 53 fish/m^3 were also conducted. At fish sizes between 5 and 12 cm TL, estimated annual production is approximately 50,000 kg/ha/yr (50,000 lb/acre/ yr). Fish in the sewage oxidation ponds grew signficantly faster than fish fed trout chow at optimum temperature in the laboratory, even though temperatures in the sewage ponds averaged below the optimum growth temperature. Techniques to accelerate growth rates are being explored. Exposure to gamma radiation (500 rads), known to cause significant increases in channel catfish growth rate, was found to have a similar effect on *Tilapia*. After a 20-week growth period, exposed fish weighted an average of 20% more than controls. (NT)

868. Suffern, J.S., C.M. Fitzgerald, and A.T. Szluha. 1981. Trace Metal Concentrations in Oxidation Ponds. J. Water Pollut. Cont. Fed. 53,1599

Heavy metal concentrations of Cd, Cr, Cu, Ni, Pb, and Zn in the wastewater, sludge, and biotic components of the Oak Ridge National Laboratory oxidation ponds were examined to determine whether metals accumulated in *Tilapia*. Results indicated that metal levels in the wastewater and biotic components are generally low and that the major metal reservoir is the sludge. Metals did not accumulate beyond standards in the muscle or liver of *Tilapia* grown in the oxidation ponds. This result may be partially due to the rapid growth rates of these fish (1-2 g fish^{-1} day^{-1}), with new tissue developing more rapidly than metals can accumulate. Another factor may be that the high concentrations of organic complexes in the ponds lower the availability of metals to the biota. (AA)

869. Sullivan, R., J. T. Tierney, and E. P. Larkin. 1976. Persistence of Poliovirus 1 in Soil Irrigated with Inoculated Sewage Sludge and Effluent, pp. 192-. *In* The Abstract of the Annual Meeting of the American Society of Microbiologists.

870. Surakka, Seppo. 1971. Some Observations on the Possibilities to Infiltrate Wastewater in Peatland According to Results Obtained at Kesaladen Town, Finland. Vesitalous 3(5):26-31. (Finnish-English Summary).

871. Surakka, S., and A. Kamppi. 1971. Infiltration of Wastewater into Peat Soils. SUO 22:51-57. (Finnish with English Summary)

872. Sutherland, J. C. 1977. Investigation of the Feasibility of Tertiary Treatment of Municipal Wastewater Stabilization Pond Effluent Using River Wetlands in Michigan. Final Report to the National Science Foundation, William and Works, Inc., Grand Rapids, MI. 171 pp. (NTIS PB 275 283)

The engineering feasibility of using Michigan river wetlands for tertiary treatment of municipal wastewater stabilization pond effluent was examined in relation to the alternatives of upland spray irrigation and chemical tertiary treatment. Seventy-five Southern Peninsula rural municipalities with populations ranging from 360 to 2,800, served by treatment ponds, and with proximal streams, were studied by means of aerial reconnaissance. Of these, 35%-40% were estimated to have a viable wetland alternative for tertiary treatment. The wetland method is estimated to be the most cost-effective at pond-wetland distances less than 4 miles. The anticipated low or zero land cost and minimum of on-site hardware are favorable capital cost advantages. Operational energy consumption would be minimized by low site pressure-head requirements and the generally low-lying position of river wetlands. The average potential capital cost savings in use of wetlands would be approximately $320,000 (1977 dollars) relative to upland irrigation, and approximately $150,000 relative to chemical treatment. (AA)

873. Sutherland, J. C. 1979a. The Vermontville, Michigan, Wastewater-grown Volunteer Seepage Wetlands: Water Quality and Engineering Implications. In J.C. Sutherland and R. H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI.

The municipal wastewater treatment system at rural Vermontville, Michigan (pop. 975), consists of two faculative stabilization ponds (10.9 ac area), followed by four flood irrigation fields (11.5 ac area). The fields are nearly overgrown with volunteer emergent aquatic vegetation, mainly cattail (Typha spp.). Wastewater (0.068 MGD average inflow) is released from the ponds into the fields between June and November. Low field berms contain the water until it infiltrates and percolates to the groundwater at 15-25 ft. depths. Minor surface overflow sometimes occurs. No cutting or removal of vegetation has been done in the six-season history of the fields.

The wetland appears to add nitrogen species and phosphorus to the irrigated water. Anaerobic decomposition (thin organic soil mat) and release of nutrients by the standing crop are likely causes of the increases in these nutrients. Greater than 97% of the P released from the stabilization ponds is removed in the soils beneath the fields before the percolating effluent reaches the ground water body.

Operation and maintenance activities at Vermontville include only mowing of grassed wetland berms, manual valve control (8 hr/wk during 5-month irrigation season) and water quality monitoring. Wetland field maintenance seems not to be needed. Capital costs for volunteer seepage wetland systems, compared to upland spray irrigation, would be rougly 92% (0.5 MGD), 75% (0.1 MGD), and less at still lower flows.

Any deliberate construction of volunteer seepage wetlands for wastewater treatment in Michigan should be done with overflow prevention in mind because of strict P effluent limitations. Such construction could be technically feasible on fine-grained but noncohesive soils (hydraulic conductivity 10^{-3} - 10^{-4} cm/sec) which can be selectively compacted during construction. (AA)

874. Sutherland, J.C. 1979b. A Wetland Wastewater Feasibility Determination Procedure and Related Subjects for Discussion and Research. Presented at the American Water Works Association Research Foundation, Water Reuse Symposium held 25-30 March 1979 in Washington, DC. 9 pp. plus supplement.

Determination of feasibility involves at least ten major categories of consideration: 1) Wastewater treatment needs (wastewater quality, effluent limitations, required removals, and wastewater volume. 2) Wetland distance. 3) Wetland ownership. 4) Wetlands protection legislation (federal, state, and legislation with regard to particular wetlands). 5) Wetland factors in wastewater treatment (modes of water exit from the wetland, residence time, vegetation uptake). 6) Special wetland characteristics and relationships (world-reference values, regional and local values, needs which wastewater application might satisfy). 7) Wetland adequacy for wastewater treatment (with unaltered natural setting, with altered natural setting, degree of certainty). 8) Environmental impact (upon the wetland, after the wetland). 9) Preliminary design. 10) Cost-effectiveness. The categories should be considered in the order given, but there should be savings in time if categories 2-4, 5-6, and 7-10 are addressed concurrently. In preparing the above outline, the following questions occur:

1) Could wastewater grown wetlands be beneficially used as sanctuaries for rare, sensitive, or endangered plant or animal species?
2) What are the ecological concerns vis-a-vis the winter application of wastewater to seepage wetlands under temperate climate conditions?
3) How much wastewater (inches per week) should be added to a wetland?
4) Are there any classifications (e.g., USFWS-Cowardin, et al.) of wetland that should be excluded a priori from wastewater application?
5) Are the transformation and removal of nitrogen in wetlands well enough understood that a compilation or "systematics" on the subject from the existing literature would serve in lieu of detailed field studies as a basis of design for wastewater treatment/disposal?
6) Are the phosphorus removal/immobilization factors well enough understood in flow-through wetlands that existing knowledge would suffice, in place of detailed stuldies, as a basis of design?
7) How should new volunteer wetlands which exist solely because of wastewater application be managed? (AA)

875. Sutherland, J.C. 1981. Economic Implications of Using Wetlands for Wastewater Treatment, pp. 295-306. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

The cost of using Michigan riverine wetlands for (hypothetical) treatment of pond-stabilization municipal wastewaters from small, mostly rural populations (range of flows, 0.038 - 0.35 MGD) were approximated in 1976-

1977, and are herein updated to Spring, 1981 (ENR construction cost index). The capital costs (C, in $1,000's) depend strongly upon distance from ponds to wetland (D, in miles), with C = 117D + 262. Forceline costs dominate in this relationship. Wastewater application would be at hydraulic loadings of less than 1 in/wk in all instances.

The Houghton Lake Sewer Authority (Michigan) recently added a natural state-owned peatland tertiary treatment system to its stabilization pond-seepage pond facilities which serve approximately 6,000 full-time and 14,000 seasonal population equivalents. Similar updating of actual capital costs (January, 1978 to Spring, 1981) yields the approximate figure of $507,000, excluding engineering related costs, for the peatland system. There are not costs for the use of land.

The 1980 wetland operation and maintenance costs borne by HLSA totaled approximately $19,000, including labor plus overhead (16%), pumping-electrical (16%), administration (8%), vehicle use (3%), repair-replacement (0.5%), lab equipment (3.5%), and state-required wildlife and vegetation studies (53%).

Before the HLSA peatland system concept was approved and funding obtained (Municipal Construction Grants Program), six years of scientific investigation (University of Michigan Wetlands Ecosystem Research Group) and hundreds of person-hours in coordination efforts (HLSA, Williams & Works) were invested at costs of $1 million to $2 million. These costs, compared to projected capital savings of $800,000 relative to the upland irrigation alternative, were borne by Michigan and U.S. taxpayers. Although experience with natural wetland treatment systems may lead to reduction in documentation time and monetary costs in future situations, significant documentation effort should, nonetheless, be anticipated because of the perceived values and individuality of natural wetlands.

Operation and maintenance costs related to the volunteer wetland-dominated soil seepage system that treats pond-stabilized wastewater from the Village of Vermontville, Michigan (pop. 900) were $4,800 annually, of which 43% are for environmental monitoring. (AA)

1092. Sutherland, J.C. In press.

876. Sutherland, J.C., and F. Bevis. 1979. Reuse of Municipal Wastewater by Volunteer Freshwater Wetlands, pp. 762-782. In: American Water Resources Association, Proceedings of the Water Reuse Symposium held 25-30 March 1979 at Washington, DC. Vol. 1. Denver, CO.

The volunteer wetland vegetation-organic mat complex at Vermontville actually adds phosphorus to wastewater during the late spring and summer irrigation season. Consequently, the wetland waters overflowing at the final discharge contain phosphorus in slight excess of permitted levels, absent a significant amount of diluting wastewater which has previously been filtered through the inorganic soils. Phosphorus removal adequate to satisfy strict effluent requirements is accomplished only by seepage from the wetlands through the inorganic soil substrate.

No field maintenance has been required at Vermontville. There are no bare soil (tilled) areas to be plugged through siltation caused by rain splash, spray irrigation, or flood-suspension of inorganic soils. The Vermontville wetlands have shown buildup of three or four inches (0.1 m) of organic residues largely in the form of cattail straw after six irrigation seasons. Over the 20-year design period the net accumulation would likely be less than 1 ft (0.3 m) due to progressive compaction and further decomposition of older plant residues. Tree control is not needed at Vermontville, although one of the fields may soon be overgrown with willow whips. On fields which might depend upon a thin compacted soil zone or other seepage restricting improvement, tree control might be needed to maintain the integrity of the conditioned soil zone.

The uptake of phosphorus by the prevailing cattail standing crop is approximately 20% of the phosphorus released into the wetlands. Cattail harvesting would therefore be a means of reducing effluent phosphorus. But harvesting is not needed for phosphorus removal in seepage wetland settings where subsurface soil types and volumes are adequate to effect streams.

Casual observation in 1978 reveals the wastewater-grown wetlands have significantly added to the acreage of suitable, adequately isolated habitat for waterfowl and other wildlife in the Vermontville area.

877. Sutherland, J. C., and R. H. Kadlec (eds.). 1979. Wetland Utilization for Management of Community Wastewater. Abstracts of a conference. Held 10-12 July 1979 at Higgins Lake, MI. 31 pp.

This document is a collection of 24 abstracts of presentations on wetland treatment systems in the United States and Canada given at the conference. Descriptions of a number of the wetland treatment sites are given in Appendix B of this report. (EP)

878. Sutton, D. L., and R. D. Blackburn. 1971. Uptake of Copper by Water Hyacinth. Hyacinth Control J. 9:18-20.

879. Sutton, D. L, and W. H. Ornes. 1975. Phosphorus Removal from Static Sewage Effluent Using Duckweed. J. Environ. Qual. 4(3):367-370.

Two experiments were conducted in containers to evaluate the influence of various concentrations of static sewage effluent on the growth of duckweed and to determine the rate of P removal and harvesting effects on growth rates. Several replicates were provided to ensure data validity. Maximum growth rates were achieved at 25% effluent plus 75% pond water. Increased effluent concentration did not increase the growth rate but did affect an increase in P uptake and protein content of plant tissues. There is a positive correlation between P concentration in the water and duckweed uptake rate up to 2.1 microgram ml. With continued nutrient input, half of the duckweed could be harvested every 4 days. (AA)

880. Sutton, D. L., and W. H. Ornes. 1977. Growth of *Spirodela polyrhiza* Static Sewage Effluent. Aquatic Botany 3:231.

881. Swett, D. 1979. A Water Hyacinth Advanced Wastewater Treatment System, pp. 233-255. In: R.K. Bastian and S.C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division, Washington, DC.

A one year field experiment, in Coral Springs, Florida, (pop. 30,000), at the 378,530 lpd (100,000 gpd) level has demonstrated that a system of 5,035 m^2 (54,200 ft^2) of water hyacinth (Eichhornia crassipes) lagoons can provide advanced treatment to effluent from an activated sludge plant by achieving removal rates of 67% for total suspended solids, 98% for biochemical oxygen demand, 97% for total N and 79% for total P. Biomass produced by the system offers a potential for energy, fertilizer or fodder production. (AA)

882. Szczepanska, W., and A. Szczepanski. 1973. Emergent Macrophytes and Their Role in Wetland Ecosystems. Polskie Archiwum Hydrobiologgi 20(1):41-50.

883. Tate, R. L. III, and R. E. Terry. 1980. Effect of Sewage Effluent on Microbial Activities and Coliform Populations of Pahokee Muck. J. Environ. Qual. 9(4):673-677.

The effect of sewage effluent was measured on microbial activity in Pahokee muck. Test plots were amended at weekly intervals with sewage effluent at a rate of 5 cm/wk. In general, the indigenous microbial activity of the effluent-amended soil was greater than that of the soil which was water-amended or untreated. An increase in indigenous activity occurred with the addition of the sewage effluent to the soil, and then declined steadily throughout the week between sewage additions. The increase in activity immediately after amendment reflected the biochemical oxygen demand of the effluent. Anaerobic bacterial populations did not differ significantly between the sewage-effluent or water-amended samples or unamended soil plots. However, significant variations were noted for various sample dates, most likely resulting from soil moisture changes. The augmented dehydrogenase activities and generally elevated carbon metabolic rates in amended soils indicate that microbial activity in the muck was stimulated. Coliform bacteria passed through the soil profile, but the increased moisture, not the nutrients, of the sewage effluent stimulated the oxidation of soil organic matter, thereby stimulating soil subsidence. Therefore, a sewage disposal plan involving cultivated organic soils must be viewed as a threat to the longevity of the soils. (WR)

884. Tchobanoglous, G. 1979. Wetland Systems for Wastewater Treatment in Cold Climates: An Engineering Assessment. Report to U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH. 43 pp.

885. Tchobanoglous, G., J. Colt, and R. Crites. 1979. Energy and Resource Consumption in Land and Aquatic Treatment Systems. Presented at the Energy Optimization of Water and Wastewater Management for Municipal and Industrial Applications Conference, Department of Energy, New Orleans, LA, 10-13 December, 1979. 12 pp.

886. Tchobanoglous, G., and G. L. Culp. 1980. Wetland systems for wastewater treatment: an engineering assessment, pp. 13-42. In S. C. Reed, and R. K. Bastian (eds.), Aquaculture Systems for Wastewater Treatment: An Engineering Assessment. EPA 430/9-80-007. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division, Washington, DC.

The use of natural and artificial wetlands for the treatment of wastewater is examined in this engineering assessment. The primary objective of the assessment was to answer the question of whether the technology of using wetlands for the treatment of wastewater is ready for routine use and, if not, what must be done to make it a reality. On the basis of 1) treatment efficiency and reliability, 2) availability of design criteria and procedures, 3) availability of proven managment techniques, 4) energy and resource consumption, 5) costs, and 6) health risks, it is concluded that the current status of wetlands technology is not yet developed to the point where the use of wetland systems can be considered routine. Data and information that must be developed before the design of wetland systems can become a rational undertaking are identified and discussed. (AA)

887. Tchobanoglous, G., R. Stowell, R. Ludwig, J. Colt, and A. Knight. 1979. The Use of Aquatic Plants and Animals for the Treatment of Wastewater: an Overview, pp. 35-55. In S. C. Reed, and R. K. Bastian (eds.), Aquaculture Systems for Wastewater Treatment: An Engineering Assessment. EPA 430/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division, Washington, DC.

Aquatic systems employing plants and animals have been proposed as alternatives to conventional wastewater treatment systems. The fundamental difference between conventional and aquatic systems is that in the former, wastewater is treated rapidly in highly managed environments, whereas in the latter, treatment occurs at a comparatively slow rate in essentially unmanaged natural environments. The consequences of this difference are 1) conventional systems require more construction and mechanization but less land than aquatic systems, and 2) conventional processes are subject to greater operational control and less environmental influence than aquatic processes. The major stimulus for further research into the fundamentals, design, and management of aquatic systems is the potential for reducing the construction, operation, and maintenance costs for wastewater treatment. The general concepts involved in the design and use of aquatic systems are presented and the implications are discussed in this overview. (AA)

888. Teal, J.M. and I. Valiela. 1973. The Salt Marsh as a Living Filter. Mar. Tech. Soc. Jour., 7: 19-21.

889. Teal, J. M., and I. Valiela. 1975. Enrichment of Coastal Wetlands. Woods Hole Oceanographic Institute. Woods Hole, MA.

Nutrient enrichment of coastal wetlands enhances production of both plant and animal components. Nitrogen accounts for most of the effect. Pollutants tend to be bound on sediments but are also taken up by organisms in proportion to their mobility.

890. Tenney, M. W., W. F. Echleberger, Jr., K. J. Guter, and J. B. Carberry. 1972. Nutrient Removal from Wastewater by Biological Treatment Methods, pp. 391-421. In H. E. Allen and J. E. Krammer (eds.), Nutrients in Natural Waters. John Wiley and Sons, Inc., NY.

891. Teskey, R. O., and T. M. Hinckley. 1977a. Impact of Water Level Changes on Woody Riparian and Wetland Communities. Vol. I: Plant and Soil Responses to Flooding. FWS/OBS-77/58. U. S. Fish and Wildlife Service. 30 pp.

Volume I is a scientific literature review detailing the impact of water level changes on growth and development of important riparian and wetland trees and shrubs and describing physiological mechanisms. It is applicable to all geographical areas in the contiguous 48 states.

892. Teskey, R. O., and T. M. Hinckley. 1977b. Impact of Water Level Changes on Woody Riparian and Wetland Communities. Vol. II: The Southern Forest Region. FWS/OBS-77/59. U. S. Fish and Wildlife Service. 30 pp.

893. Teskey, R. O., and T. M. Hinckley. 1977c. Impact of Water Level Changes on Woody Riparian and Wetland Communities. Vol. III: The Central Forest Region. FWS/OBS-77/60. U.S. Fish and Wildlife Service. 36 pp.

894. Teskey, R. O., and T. M. Hinckley. 1978a. Impact of Water Level Changes on Woody Riparian and Wetland Communities. Vol. IV: Eastern Deciduous Forest Region. FWS/OBS-78/87. U.S. Fish and Wildlife Service. 36 pp.

This volume of the series covers the important woody plant species in the Eastern Deciduous Forest Region, which encompasses the area from southern Minnesota eastward to the Appalachians.

895. Teskey, R. O., and T. M. Hinckley. 1978b. Impact of Water Level Changes on Woody Riparian and Wetland Communities. Vol. V: Northern Forest Region. FWS/OBS-78/88. U.S. Fish and Wildlife Service. 54 pp.

This volume of the series covers the important woody plant species in the Northern Forest Region, which encompasses the Great Lakes region from Minnesota eastward to the Atlantic Ocean.

896. Teskey, R. O., and T. M. Hinckley. 1978c. Impact of Water Level Changes on Woody Riparian and Wetland Communities. Vol. VI: Plains Grassland Region. FWS/OBS-78/89. U.S. Fish and Wildlife Service. 54 pp.

This volume of the series covers the important woody plant species in the Plains Grassland Region, which covers the middle west of the United States from eastern Montana to western Minnesota and south to Texas.

897. Teskey, R. O., and T. M. Hinckley. 1980. Impact of Water Level Changes on Woody Riparian and Wetland Communities. Vol. VII: Mediterranean Region, Western Arid and Semi Arid Region. FWS/OBS-78/93. U.S. Fish and Wildlife Service. 54 pp.

898. Texas Dept. of Health. 1976. Water Hyacinth Culture for Wastewater Treatment. Austin, TX.

899. Thomson, S.V. and R.M. Allen. 1974. Occurrence of Phytophthora species and Other Potential Plant Pathogens in Recycled Irrigation Water. Plant Dis. Rep. 58:945-949.

900. Thorhaug, A. 1977. Ecological Study of the Effects of Power Plants on Benthic Macroplant Microcosms in Subtropical and Tropical Estuaries. Progress Report, 1976-77. Miami Univ., FL. 34 pp.

The effect of two fossil fuel and two nuclear plants on a near-shore seagrass community was studied in South Biscayne Bay, Dade County, Florida, over the past four years. The focus of the study was to delineate the effects that a series of various pollutants have had on the dominant system of seagrass Thalassia testudinum and its related community. Data are included from studies on the effects of heavy metals, waste heat, and dredging activities, with emphasis on thermal pollution. In order to separate the perturbation of the specific pollutant from the natural fluctuations of the system, efforts were made to understand the dynamic processes in adjacent untouched areas. (NT)

901. Tietjen, W. L., and J. C. Carter. 1980. Phosphate Uptake by River Swamp Ecosystems. Georgia Southwestern College. Americus, GA.

902. Tiffin, L. O. 1977. The Form and Distribution of Metals in Plants: an Overview, pp. 315-334. In H. Drucker, and R. E. Wildung (eds.), Biological Implications of Metals in the Environment. ERDA Symposium Series No. 42. Energy Research and Development Administration, Washington, DC.

903. Tilton, D. L. 1976. Recovery of Nutrients from Peatlands used for Tertiary Treatment, pp. 307-327. In D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

The potential for wetlands to simultaneously act as tertiary treatment systems and produce a harvestable crop is considered. Characteristics of organic soils which are important to their use as tertiary treatment alternatives and which influence crop production are discussed. In addition, current and potential uses of wetlands are described, and the compatibility of each use with tertiary treatment is evaluated.

Analysis of the Porter Ranch Peatland project (Michigan project) indicates that vegetable and/or field crop production is not feasible, but silviculture of appropriate pulpwood species may be possible. Forestry provides advantages in harvesting, nutrient storage, and low risk due to heavy metals and viruses. However, forestry may not be feasible if waterfowl production is a management goal for the area or if nutrient requirements of the trees are not met by nutrient additions in the effluent.

904. Tilton, D. L. 1977a. The Effects of Secondary Effluent on the Plant and Soil Components of a Northern Wetland Ecosystem. In R. H. Kadlec, D. L. Tilton, and J. A. Kadlec (eds.), Feasibility of Utilization of Wetland Ecosystems for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent. Semi-annual Rept. No. 5. Univ. of Michigan, Ann Arbor.

This paper describes the effect of discharging 12 million gallons of secondarily treated effluent on the growth of vascular plant species. The nutrient content of certain ecosystem components is described. (WE)

905. Tilton, D. L. 1977b. Nitrogen Dynamics in Northern Freshwater Wetlands. Bulletin of the Ecological Society of America.

906. Tilton, D.L. 1978. Wastewater Treatment via Wetland Irrigation: Nutrient Dynamics, pp. 178-197. In: C.B. DeWitt and E. Soloway (eds.), Wetlands:

Ecology, Values, and Impacts. Proceedings of the Waubesa Conference on Wetlands, 2-5 June, 1977. Madison, WI. Institute for Environmental Studies, Univ. of Wisconsin, Madison.

The effect of discharging approximately 10 million gallons of secondary effluent onto a ten acre section of wetland is described. Total dissolved P, NH_4 - N, NO_3 + NO_2 - N, and Cl were measured in the effluent and in surface waters various distances (30-255 m) from the discharge location. Total dissolved P and NO_3 + NO_2 - N in surface waters had returned to background concentrations within 30 m of the discharge, while Cl tended not to decrease with distance as much as the more biologically active ions. Element budgets showed the 99 percent, 95 percent and 71 percent of the total input of nitrate+nitrite-N, total dissolved P, and NH_4 - N, respectively, were immobilized within 30 m of the discharge site. Element immobilization occurred by a combination of physical and biological processes.

907. Tilton, D.L. 1981. The Environmental Impacts Associated with Developments in Wetlands, pp. 357-362. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

The environmental impacts associated with the utilization of wetland ecosystems for stormwater management, wastewater treatment, or other purposes is not widely understood. This paper suggests a conceptual framework which is useful for the preparation of wetland environmental impact assessments and presents several examples of impacts associated with altering the energy budget, nutrient budget, or hydrologic budget of various wetland ecosystems.

908. Tilton, D.L. and R.H. Kadlec. 1979. The Utilization of a Freshwater Wetland for Nutrient Removal from Secondarily Treated Wastewater Effluent. J. Environ. Qual. 8(3):328-334.

To test the feasibility of utilizing a fresh-water wetland for tertiary wastewater treatment, secondarily treated wastewater was applied to a wetland in the northern lower peninsula of Michigan. During the discharge of 38,840 m^3 (10,260,000 gal) and 23,520 m^3 (6,213,000 gal) of secondarily treated wastewater in 1976 and 1977, respectively, surface water quality, plant productivity, and nutrient status of plants and soils were measured. In 1976 the concentration of (nitrate + nitrite)-N averaged 0.36 mg/l in the effluent and 0.01 mg/l at stations 25 m from the discharge pipeline. Total dissolved P (TDP) averaged 0.41 mg/l in the effluent and 0.11 mg/l at sampling stations 25 m from the discharge. The efficiency of P removal from the effluent was greater when surface water depth were 6 cm compared to 30 cm. Ammonium - N concentrations were rarely higher in the effluent compared to background concentrations in the wetland surface waters. In 1977 a point source distribution system was used. The effluent averaged 1.50 mg/l nitrate - N and 1.57 mg/l TDP. Within 30 m, nitrate - N was 0.10 mg/l in the surface water and within 80 m TDP was 0.07 mg/l. Biomass of live plants in 1976 was somewhat greater near the pipeline compared to control areas. Leaves of cattail (Typha latifolia) were longer near the pipeline in 1976 compared to control areas. Chemical analysis of sedge (Carex spp.) leaves and roots, standing dead and litter sampled in 1976 showed no significant differences in N concentrations among sampling locations, but P concentrations were higher in leaves and roots 6 m from the pipeline compared to control areas. (BA)

909. Tilton, D. L., R. H. Kadlec, and J. Linde. 1977. Surface Water Chemistry and Element Budgets of a Wetland Used for Wastewater Treatment, pp. 53-126. In R. H. Kadlec, D. L. Tilton, and J. A. Kadlec (eds.), Feasibility of Utilization of Wetland Ecosystems for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent. Semi-Annual Report No. 5. Univ. of Michigan, Ann Arbor.

The effect of discharging approximately 10 million gallons of secondary effluent onto a ten acre section of a northern Michigan wetlands is described. Total dissolved P, NH_4-N, NO_3+NO_2-N, Cl, Na, Ca, Mg, K, Ni, Zn, Cu, Pb, COD, pH, alkalinity, hardness, and specific conductivity were measured in the effluent and in surface waters various distances (30 - 225 m) from the discharge locations. Total dissolved P, NO_3+NO_2-N, and pH in surface waters had returned to background concentrations within 30 m of the discharge. Alkalinity and hardness decreased to background concentrations 50 m from the discharge site, while Cl, Ca, Mg, Na, and to a lesser extent, K tended not to decrease with distance as much as the more biologically active ions. COD was lower in the effluent than surface waters in the wetland.

Element budgets showed that 99%, 95% and 71% of the total input of nitrate+nitrite-N, total dissolved P, and NH_4-N, respectively, were immobilized within 30 m of the discharge site. Equivalent immobilizations of the total input for K, Mg, Na, Ca, and Cl were 69%, 42%, 39%, 32%, and 30%, respectively. Element immobilization occurred by a combination of physical and biological processes. (AA)

910. Tilton, D. L., R. H. Kadlec, and C. J. Richardson (eds.). 1976. Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor. 343 pp.

The symposium was held to discuss the feasibility of using freshwater wetland ecosystems to remove certain chemicals from secondarily treated wastewater before they enter lakes, streams, and groundwaters. The following represents a general list of those areas of consideration: (1) Hydrology: fate of water beyond the wetlands, loading rate, flow rate within the wetland; (2) Nutrient Dynamics and Accumulation: efficiency of treatment, mechanism of nutrient removal from wastewater, loading rate; (3) Environmental Impacts: changes in species composition, habitat protection, health; (4) Legal Aspects: enabling policy and legislation; (5) Economic Considerations: savings in construction cost, benefits associated with protection of environmental quality; (6) Land Use: compatible with other traditional uses of wetlands, policies associated with state and federal wetlands; and (7) Design Considerations: artificial or natural wetlands, method of effluent discharge, schedule of pumping, determination of discharge rate. (NT)

911. Tilton, D.L., and B.R. Schwegler. 1978. The Values of Wetland Habitat in the Great Lakes Basin. pp. 267-277, In: P.E. Greeson, J.R. Clark, and J.E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. American Water Resources Association, Minneapolis, MN.

912. Tischer, R. G., and L. R. Brown. 1962. Mechanism of Algae-Bacteria Complexes in Oxidation Ponds. Progress Rept. Mississippi State Univ., State College. 50 pp.

During the course of the investigation it was found that practically all of the ponds tested contained some thermophilic micro-organisms. Studies conducted with these thermophiles indicated that they held considerable potential as a means of stabilizing domestic sewage. It seemed desirable to include in the report only that material relating to sewage stabilization by aerobic thermophiles. (NT)

913. Tortell, P. The Utilization of Waste Nutrients for Aquaculture. Presented at IAWPR Developments in Land Methods of Wastewater Treatment and Utilization International Conference, held Oct. 23-27, 1978 in Melbourne, Australia.

Fish pond fertilization with human and animal wastes has been practiced for centuries. Sewage effluent use for aquaculture is reviewed, and integrated wastewater-aquaculture systems are analyzed. The need for large areas of land and adequate public health safeguards, and logistics of harvesting are problems that can be easily solved; consumer acceptance is more difficult to achieve. Until this obstacle can be overcome, the products of wastewater-aquaculture (unicellular algae, aquatic macrophytes, invertebrates, and finfish) can be put to other uses. There is a consensus that aquaculture has great potential as an alternative to conventional waste treatment and disposal systems. (EL)

914. Toth, L. 1972. Reeds Control Eutrophication of Balaton Lake. Journal Internat. Assoc. Water Pollution Res. 6(12):1533-1539.

Wastewater was applied to the upland edge of a reed swamp on the border of Lake Balaton in Hungary. Nutrients in the wastewater were removed effectively by passage through the swamp. (EP)

915. Tortora, L. 1978. Analysis of Phosphorus Data from Wetlands Application Site for Secondarily Treated Municipal Effluents. Master's Paper. Dept. of Environmental Engineering Sciences, University of Florida, Gainesville.

916. Tourbier, J., and R. W. Pierson, Jr. (eds.). 1976. Biological Control of Water Pollution. Univ. of Pennsylvania Press, Philadephia.

This publication contains a number of articles that are related to the topic of wastewater renovation by natural and artificial wetlands, including research performed in foreign countries. The section entitled "Biological Treatment of Wastewater" contains a number of papers that deal with specific vegetation types and their relationship to water purification. (EP)

917. Trieff, N. M. et al. 1976. Sewage Treatment by Controlled Eutrophication Using Algae and Artemia, pp. 231-239. *In* Biological Control of Water Pollution. Univ. of Pennsylvania, Philadelphia.

918. Trimberger, J. 1972. Production of Fathead Minnows (*Pimephales promelas*) in a Municipal Wastewater Stabilization System. Michigan Department of Natural Resources, Grand Rapids. 5 pp.

Sewage oxidation ponds may provide a valuable culture media for rearing forage fish for piscivorous species--especially muskellunge. The fish manager should consider using lagoons to rear forage fish for restocking lakes following chemical treatment.

919. Tsai, C. 1975. Effects of Sewage Treatment Plant Effluents on Fish: a Review of the Literature. Publication No. 36. Chesapeake Research Consortium, Inc., Baltimore, MD.

920. Tsai, C. 1978. Impact of Wastewater Treatment Plant Discharges, pp. 149-150. *In* K. C. Flynn and W. T. Mason (eds.), The Freshwater Potomac - Aquatic Communities and Environmental Stresses. Proceedings of a symposium held in January 1977 at College Park, MD. Interstate Commission on the Potomac River Basin, Rockville, MD.

921. Turner, R. E., J. W. Day, Jr., M. Meo, P. M. Payonk, T. B. Ford, and W. G. Smith. 1976. Aspects of Land-treated Waste Application in Louisiana Wetlands, pp. 145-168. *In* D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

This is a summary of a short-term feasibility study utilizing a combination of overland flow and topical application of menhaden fisheries waste in a Louisiana freshwater, coastal marsh. Significant amounts (40-50%) of C, N, and P were lost to the soil-plant system when wastewater followed an overland flow route. Live standing crops were significantly higher when wastes were applied directly. Both application procedures increased net production of the three plant communities between 32-50%. Less than 5% of total nutrient application was taken up by plants. The soil-water interface is implicated as the major site of sorption, deactivation, and denitrification for both application procedures. Authors suggest use of abundant spoil disposal sites for this type of treatment system. (WE)

922. Tusack-Gilmour, D. 1980. Effluent Creates an Oasis in Nevada. Water and Wastes Engineering 17(9):22-24, 56.

The Las Vegas Wash, fed by effluents from the Las Vegas and Clare County (Nevada) wastewater treatment plants, is a lush, 4,000-acre bird and animal retreat in the desert. More than 200 species of birds and animals inhabit it, and marsh and riparian vegetation abounds. However, excessive perennial flows and flooding during summer and winter have caused extensive damage; erosion and headcutting must be remedied to preserve the Wash. Besides its present status as a wildlife habitat, several existing and proposed beneficial uses for the Wash include a recreation-park area, education and research, hunting, a flood flow conduit and urban stormwater treatment system, a wastewater effluent conduit, a potential treatment system for the removal of P, N, and other pollutants, a salinity control point for reducing TSS levels to the Colorado River system, and a source of return flow credits for expanding the water supply system. Recent progress by concerned conservation groups and public agencies has strengthened the concept of maintaining and improving this unique wetlands environment. Preservation of its distinctive features depends upon development of an overall marsh-wetlands management plan and the support to implement it. (PA)

923. U.S. Environmental Protection Agency. 1973. Tertiary Treatment with a Controlled Ecological System. Pub. No. EPA-660/2-73-022. National Water Quality Lab. Duluth, MN.

A two-stage pond system was constructed and operated as a process for polishing secondary sewage effluent. In the shallow first pond a luxuriant growth of algae was maintained. In the second stage a population of *Daphnia pulex* effectively removed the algae. Total volume of the system was 1,135 cubic meters. A program of chemical and biological monitoring was followed over a twelve-month period. Objectives were to demonstrate feasibility of the process for producing recreational-grade water, acquire operating data on a completely biological process, and determine its potential for nutrient removal. The system was operated with about 10 days' detention in each stage.

The *Daphnia* remained as the dominant zooplankton species in the second stage pond throughout the observation period, and during periods when their concentration was above 500 organisms/liter, were able to hold water transparence at Secchi disk readings around 2 meters. At such times COD reduction was above 40 percent across the system. Significant removal of nutrients occurred only during the months of July and August when nitrogen and phosphate reductions were 48 percent and 63 percent, respectively. Nutrient removal performance was hampered by occasional invasions of Daphnia or rotifers in the first stage pond, which decimated the algae population; such events were not successfully controlled and remain the principal obstacle to further development of the process.

924. U.S. Environmental Protection Agency. 1976a. Wastewater Treatment by Natural and Artificial Marshes. EPA Technology Transfer Series EPA-600/2-76-207.

925. U.S. Environmental Protection Agency. 1976b. Economic Assessment of Wastewater Aquaculture Treatment Systems. Cincinnati, OH. 118 pp.

A desk study of the economic viability of aquaculture as an alternative to conventional wastewater treatment systems was undertaken on behalf of small townships in southwest U.S.A. A total of 15 alternative treatment combinations was examined, in which aquaculture either in the form of a raceway or lagoon was adopted in 11 instances, in conjunction with various forms of preliminary biological treatment. The most cost-effective strategy for meeting particular criteria, such as the degree of removal of BOD or dissolved nutrients, or the fulfillment of advanced water treatment standards, was selected. It was demonstrated that in certain situations wastewater aquaculture presented a low-cost alternative to conventional treatment technology, but that, on the basis of current knowledge, it may not provide the most economic method of meeting stricter effluent standards. (AL)

926. U.S. Environmental Protection Agency. 1980a. Mutagenic Activity and Chemical Characterization for the Palo Alto Wastewater Reclamation and Groundwater Injection Facility. Pub. No. EPA-600/S1-81-029. Washington, DC.

At the Palo Alto Reclamation Plant 0.44 cu m/s (1 mgd) of secondary effluent is reclaimed through a series of wastewater treatment processes. Mutagenic activity was consistently found to be present in the secondary treated municipal wastewater influent to the Reclamation Facility. This activity was not reduced significantly by high time treatment, air stripping, recarbonation, or ozonation, even though these processes did remove a portion of the overall organic content of the wastewaters and many of the volatile organic compounds. Activated-carbon adsorption was effective in removing mutagenic activity to such a degree that mutagenic activity could not be found in water used for injection or that taken from monitoring wells. Chlorination resulted in an increase in mutagenic activity. A laboratory study demonstrated that this increase in activity would not result if chlorine dioxide rather than chlorine were used for disinfection. Chlorination resulted in the production of a significant concentration of non-purgeable, but otherwise unidentified, chlorinated organic compounds, as well as trihalomethanes. Formation or removal of such compounds did not seem to correlate with changes in mutagenic activity.

Air stripping by the fountain-spray system was most effective in removing volatile organic compounds, while activated carbon was responsible for removals obtained for most other organic materials.

927. U.S. Environmental Protection Agency. 1980b. Treatment of Primary Effluent by Rapid Infiltration. Pub. No. EPA-600/S2-80-207. Washington, DC

928. U.S. Environmental Protection Agency. 1980c. Municipal Solid Waste Disposal in Estuaries and Coastal Marshlands EPA-600/S2-80-212.

929. U.S. Environmental Protection Agency. 1981a. Process Design Manual for Land Treatment of Municipal Wastewater. EPA 625/1-81-013.

930. U.S. Environmental Protection Agency. 1981b. Sewage Sludge Viral and Pathogenic Agents in Soil-Plant Animal Systems. (EPA-600/S1-81-026). Washington, DC.

931. U.S. Environmental Protection Agency. 1981c. Cropping Systems for Treatment and Utilization of Municipal Wastewater and Sludge. Pub. No. EPA-600/S2-81-065. Washington, DC.

The efficiency of nitrogen stripping by intercropping forages with corn is evaluated in a three-year study at Muskegon County Wastewater Treatment Facility in Michigan. Corn is grown as the major cash crop at the Muskegon treatment facility, but experience has shown that corn is not efficient in removing nitrogen from applied wastewater except during a few short weeks during its growing season. Studies were designed to evaluate the improved nitrogen removal for the entire irrigation season when corn is no-till planted in a number of selected forage crops. In addition to nitrogen stripping studies, sludge compatibility and metal contaminated sludge studies were evaluated to determine the feasibility of applying sludge to land which is being used in a wastewater treatment system.

932. U.S. Environmental Protection Agency. 1981d. Evaluation of the Health Risks Associated with the Treatment and Disposal of Municipal Wastewater and Sludge. Pub. No. EPA-600/S1-81-030. Washington, DC.

933. U.S. Environmental Protection Agency. 1981e. Health Effects of Sewage Aerosols: Additional Serological Surveys and Search for *Legionella pneumophila* in Sewage. Pub. No. EPA-600/S1-81-032. Washington, DC.

Antibody levels to Legionella pneumophila, sero-group 1 and Hepatitis A Virus (HAV) were determined for 433 persons living within a 1.6 km radius of an activated sludge plant. Sera of children 6 to 13 years of age were also tested for antibody to Norwalk Virus. The antibody prevalence rates for L. pneumophila, HAV and Norwalk Virus were 23.2%, 31.55% and 7.1%, respectively. The prevalence of L. pneumophila antibody was higher than expected but not the others. Seroconversions were not observed except for a 4-fold rise in HAV antibody in one pair of sera suggesting new infections did not occur in the 8-month study period by any of these agents. Using an index of exposure for the number of viable organisms generated at the plant to which participants were exposed, the average index for persons with antibody to L. pneumophila or HAV, was not different from the averages of those without antibody. In addition, there was no association between how close people lived to the plant, or how long they lived in the study area, and being seropositive. These findings augment but still did not prove the previous findings that sewage aerosols emitted from this plant had no overt health effects.

934. U.S. Environmental Protection Agency. 1981f. Health Risks of Human Exposure to Wastewater. Pub. No. EPA-600/S1-81-002. Washington, DC.

In this study started in 1977, clinical and serologic evaluations of workers involved in composting of wastewater treatment plant sludge by the aerated pile method was initiated to evaluate the potential health effects of exposure to Aspergillus fumigatus and other viable and nonviable components of sludge. A health study consisting of analysis of blood specimens for liver and kidney function parameters, determination of serum and urine bile acid concentrations, physical examinations, interviews, and air and water monitoring was conducted of residents exposed to carbon tetrachloride and other toxic chemicals in drinking water as a result of contamination of domestic wells by a nearby hazardous waste dump. A study was undertaken to determine if evidence of exposure to hexachlorocyclopentadiene, hexachlorabicycloheptadiene, heptachlorobicycloheptane, and chlordene could be detected by urine analysis of workers exposed to chlorinated insecticide substances discharged to the sewer by a pesticide formulator. In order to assess the potential for health risks associated with the spray irrigation of wastewater, a clinical and virus serologic evaluation of workers and wastewater and air monitoring for viruses, pathogenic bacteria, and volatile organic chemicals was conducted. A field ecosystem study was carried out to evaluate the effects of land application of heat dried municipal wastewater treatment plant sludge (Milorganite) on vegetation, insects and medow voles. The potential health effects associated with sludge incineration and pyrolysis are also presented.

935. U.S. Environmental Protection Agency. 1981g. Helminth and Heavy Metals Transmission from Anaerobically Digested Sewage Sludge. Pub. No. EPA-600/S2-81-024. Washington, DC.

936. U.S. Environmental Protection Agency. 1981. Soil Temperature and Sewage Sludge Effects on Plant and Soil Properties. Pub. No. EPA-600/S2-81-069. Washington, DC.

A field experiment was conducted to determine the influence of soil temperature and sewage sludge on growth and composition of corn (*Zea mays L.*). Changes in soil organic matter, extractable metals, pH, bulb density, aggregation, fecal coliform, and fecal streptococcus were determined. Soil temperatures studied were 16, 27, 35, and 22C° (ambient). Sludge was applied at rates of 0, 56, and 112 metric tons per hectare. Corn yields and growth were reduced by 16C° soil temperature, and increased by heating the soil to 35C° in 1976, but the warmer soil did not significantly increase yields in 1975. The effects of soil temperature on heavy metal concentrations in plants varied according to year, metal, and plant part. Zinc concentrations generally increased with increased soil temperature. Sludge increased concentrations of Zn, Cu, Ni, and Cd in corn, radishes, legume and small grain tissues. Cd increased significantly in corn seedlings with soil temperature increase, but not in stover. The highest rate of fecal coliform and fecal streptococcus addition and the longest survival times in soil were on plots receiving the highest sludge application. Survival time varied directly with soil temperature.

937. U.S. Environmental Protection Agency. 1981. Wastewater Treatment by Rooted Aquatic Plants in Sand and Gravel Trenches. EPA-600/S2-81-091. Washington, DC.

The objective of this project was to evaluate a patented process developed by the Max Planck Institute (MPI) of West Germany for the treatment of industrial wastes, as an energy-efficient method for the treatment of municipal wastewater. The major goal was to achieve effluents meeting the United States Federal Effluent Standards by this novel biological treatment process that uses a minimal amount of mechanical equipment and does not require a great amount of manpower for normal operation. An eleven month study demonstrated that raw screened wastewater applied to the trench system at a rate not exceeding 95 m^3/d (25,000 gpd) could be treated to secondary effluent quality. Spatial requirements were about the same as for a septic tank system.

938. U.S. Environmental Protection Agency. 1981. Water Quality and Mangrove Ecosystem Dynamics. Pub. No. EPA-600/S4-81-022. Washington, DC.

Field studies were made to determine the relationship between general water quality parameters with emphasis on pesticides and metal pollutants, and the functioning of the halophytic mangroves. It was concluded, from a broad range of ecological sample analyses, that mangroves are relatively insensitive to toxic materials in the parts per million range and lower. Further, they do not significantly concentrate synthetic organics or metals to levels which could be considered harmful to detritus feeders.

1093. U.S. Environmental Protection Agency. 1983a.
1094. U.S. Environmental Protection Agency. 1983b.
1095. U.S. Environmental Protection Agency. 1983c.

939. U.S. Fish and Wildlife Service. Refuge Manual 17. Disease Prevention and Control (draft). pp. 729-757, In: Populations Management, 7RM17, National Wildlife Refuge System. Department of the Interior, Washington, DC.

940. U.S. Forest Service. 1978. Strategies for Protection and Management of of Floodplain Wetlands and Other Riparian Ecosystems. GTR-WO-12. Proceedings of the Symposium, 11-13 December 1978, Callaway Gardens, GA. Department of Agriculture, Washington, DC, 410 p.

941. Vadas, R.L., M. Keser, P.C. Rusanowski, and B.R. Larson. 1976. The Effects of Thermal Loading on the Growth and Ecology of a Northern Population of Spartina alterniflora, pp. 54-63. In G.W. Esch, and R. W. McFarlane (eds.), Thermal Ecology II. Proceedings of a symposium held at Augusta, Georgia, 2-5 April 1975. Technical Information Center, Energy Research and Development Administration. (Available from NTIS as CONF -750425).

Thermal effluents from the Maine Yankee Atomic Power Co. increased the plant densities of Spartina alterniflora during the first year of operation (1973) but reduced the densities substantially the second year (1974). Growth and flowering were initiated earlier near the heated effluent. Subsequent growth was reduced in early summer but was more normal during the late summer and fall of the first year. During the second year of operation, growth was greatly reduced, and large plants never developed. Biomass and net-production estimates at the control site compare favorably with other marshes along the east coast of North America. In the marsh affected by the thermal discharge, biomass decreased by the thermal discharge, biomass decreased by 48% in 1973 and 40% in 1974. The rhizome system of affected plants collapsed in 1974-1975. These plants, in contrast to southern forms, appear to have lost their tolerance of high temperatures. (AA)

942. Valiela, I., M.D. Banus, and J.M. Teal. 1974. Response of Salt Marsh Bivalves to Enrichment with Metal-containing Sewage Sludge and Retention of Lead, Zinc, and Cadmium by Marsh Sediments. Env. Pollution 7(2):149-157.

Growth in the bivalves Mercenaria mercenaria and Crassostrea virginica was not affected by experimental additions of metal-containing sewage sludge and fertilizers to salt marsh plots. Nodiolus demissus, a mussel inhabiting the marsh surface, did grow better under the same fertilizer treatments. Input-output, budgets show that Pb was trapped in the sediments with virtually no loss to deeper waters. Zn and Cd also accumulated in the sediments but there was some transport away from the salt marsh surface. Increases in Zn and Cd, but not Pb, were detected in the creek bottom detritus downstream. All three species of shellfish showed no increases in Pb or Zn contents, but all showed increases in Cd.

943. Valeila, I., and J. M. Teal. 1972. Nutrient and Sewage Sludge Enrichment Experiments in a Salt Marsh Ecosystem. Intecol. Symp. on Physiological Ecology of Plants and Animals in Extreme Environments. Dubrovnik, Yugoslovia.

944. Valiela, I., and J. M. Teal. 1978a. Inputs, Outputs, and Interconversions of Nitrogen in a Salt Marsh Ecosystem. *In* R. Jeffereies and A. Davy (eds.), Ecological Processes in Coastal Environments. Brit. Ecol. Soc. Symp. Blackwell.

945. Valiela, I., and J.M. Teal. 1978b. Nutrient Dynamics: Summary and Recommendations. pp. 259-263, *In*: R.E. Good, D.F. Whigham, and R.L. Simpson (eds.), Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, Inc., New York, NY.

946. Valiela, I., J. M. Teal, and N. Y. Persson. 1976. Production and Dynamics of Experimentally Enriched Salt Marsh Vegetation: Below Ground Biomass. Limnol. Oceanogr. 21:245-252.

Root growth increased during the early growing season in *Spartina alterniflora* salt marsh plots. While fertilization with nitrogenous fertilizer did not affect initial growth, a marked decrease in root biomass followed the spring peak particularly where nutrient doses were highest. A sharp reduction in roots occurred in enriched areas covered by *Spartina patens*, although as with *S. alterniflora*, aboveground biomass increased. Roots disappeared during autumn leaving rhizomes as the only part of the plants to overwinter. The maximum standing crop for roots was 0.2 cm deep, for rhizomes 2.5 cm. Net annual underground production was calculated from annual increments in dead matter belowground. Total production, underground and aboveground, exceeds that of any marine-vegetation ranking from 3,900 to 6,600 g m^2 yr^1 in *S. alterniflora* areas and 3,200 to 6,200 g m^2 yr^1 in *S. patens* areas. Fertilization increased production particularly aboveground where dead plant parts are subject to export. (AA)

947. Valiela, I., J. M. Teal, and W. Sass. 1973. Nutrient Retention in Salt Marsh Plots Experimentally Fertilized with Sewage Sludge. Estuarine Coastal Mar. Sci. 1(3):261-269.

Growing population on the NW Atlantic Coast has increased the contamination of coastal wetlands with sewage wastes. Effects of sewage on salt marsh ecosystems by experimentally treating salt marsh plots with sewage sludge was studied. Plots 10 m in diameter were fertilized once every two weeks with commercially available sewage sludge and nutrient losses measured in ebbing tidal water. The experimental plots were located in basins drained by single small ditches to allow sampling of ebbing tidal water from each plot. Concentration of ammonia nitrogen, nitrate+nitrite nitrogen, nitrite nitrogen, phosphate phosphorus and total phosphorus, respectively, in water leaving the treated plots was measured. Sea water temperature negatively affected phosphate phosphorus losses. Principal losses were in the form of ammonium and phosphate and were related to dosage applied and height of tide following application. Salt marsh systems are sufficiently flexible to use as much nitrogen as is available regardless of the supply mechanisms. They may act as effective removers of excess inorganic nitrogen. Results suggest that adequately managed salt marshes may be considered as potential tertiary treatment systems for sewage effluent.

948. Valiela, I., J. M. Teal, and W. J. Sass. 1975. Production and Dynamics of Salt Marsh Vegetation and the Effects of Experimental Treatment with Sewage Sludge. J. Appl. Ecol. 12(3):973-981.

The response of salt marsh vegetation to sewage applications is determined. The seasonal pattern of growth and decay of organic matter is studied, and changes in the botanical composition of vegetation are measured. Fertilization with a 10-6-4 sewage sludge fertilizer increased total peak standing crops of salt marsh vegetation despite the presence of considerable amounts of heavy metals and chlorinated hydrocarbons in the sludge. (EL)

949. Valiela, I., J. M. Teal, S. Volkmann, D. Shafer, and E. J. Carpenter. 1978. Nutrient and Particulate Fluxes in a Salt Marsh Ecosystem: Tidal Exchanges and Inputs by Precipitation and Groundwater. Limnol. and Oceanogr. 23: 798-812.

Waterborne nutrients enter Great Sippewissett Marsh through groundwater, rain, and tidal flooding. The ebb of tidal water removes nutrients. During summer, uptake by marsh biota leads to net import of nutrients. The increased export of ammonium in August may be due to leaching from senescent marsh plants. There is a net annual export of ammonium, nitrate, nitrite, dissolved organic (DON) and particulate (PN) nitrogen, particulate carbon (PC), and phosphate. Ammonium, DON, and PN are the major forms of nitrogen exported. Nutrient concentrations in coastal and marsh water are correlated, and marsh exports could contribute substantially to nutrient supplies of coastal waters.

Groundwater entering the marsh provides primarily NO_3-N and DON. Nutrient inputs through precipitation consist primarily of DON, NO_3-N and NH_4-N. Particulate materials in rain have a high C:N ratio, contributing little to enrichment of the nitrogen-limited salt marsh. Groundwater carries over 20 times the amount of nutrients brought in by rain. The nitrogen provided by both sources is more than enough to support annual plant growth. Inputs of nitrogen by groundwater are therefore important to the nitrogen economy of a salt marsh.

About half the dissolved inorganic nitrogen brought into the marsh by groundwater is converted to and exported as PN. The marsh thus transforms the nitrogen that would have been used by primary producers into a form suitable for consumers such as shellfish. Large amounts of apparently refractory DON enter the marsh in groundwater and similar amounts are exported by tides. PC exported to coastal water is equivalent to 40% of the net annual production of Spartina alterniflora, the dominant marsh plant. (AA)

950. Valiela, I., and S. Vince. 1976. Assimilation of Sewage by Wetlands, pp. 234-253. In M. Wiley (ed.), Estuarine Processes, Vol. 1. Uses, Stresses and Adaptation to the Estuary. New York. 541 pp.

Wetlands have attracted attention as potential components of waste treatment systems because of typically high primary productivity, high decomposer activity, anaerobic condition and large adsorptive areas in the sediments. These properties seem to provide wetlands with the ability to degrade and eliminate contaminants in wastewaters, and have been studied in a variety of wetland habitats throughout the world (salt and brackish marshes, polders, cypress, papyrus and mangrove swamps, freshwater marshes and bogs). Although each wetland type differs, current results from marshes show that N and P compounds are removed from contaminated or waste waters. Heavy metals from sludges are retained by marsh muds, but the effectiveness varies considerably for different metals. Petroleum hydrocarbons accumulate in marsh muds and may be actively decomposed, particularly at low levels of contamination. Chlorinated hydrocarbons have high affinities for marsh sediments and can be altered by microrganismal activity. Preliminary evidence indicates that counts of coliform bacteria may be reduced in tidal water that floods marshes. Little is known about the thresholds of wetlands to tolerate the impacts of wastewater, but studies in chronically contaminated sites show that marshlands function well even in severely polluted areas. (WE)

951. van der Valk, A. G., C. B. Davis, J. L. Baker, and C. E. Beer. 1979. Natural Freshwater Wetlands as Nitrogen and Phosphorus Traps for Land Runoff, pp. 457-467. In P. E. Greeson, J. R. Clark, and J. E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. Proceedings of the National Symposium on Wetlands held in Lake Buena Vista, FL, 7-10 Nov. 1979. Tech. Publ. No. TPS 79-2. Amer. Water Resour. Assoc., Minneapolis, MN.

All types of natural wetlands behave as N and/or P traps at least seasonally and, as a consequence, improve the quality of polluted water passing through them. Annual efficiency of N and P removal by a wetland is primarily a function of the wetland's hydrologic regime, litter fall pattern, and rate of litter decay. Improving the efficiency of N and P removal by proper management of a wetland is at least theoretically possible in some cases. (AA)

952. Van Raalte, C.D. 1977. Nitrogen Fixation in Salt Marshes - A Built-in Plant Fertilizer. Oceanus 20(2):58-63.

The structure of salt marsh ecosystems and the effect of pollutants on them has attracted the interest of agricultural researchers looking for ways to maintain crop yields while reducing nitrogen requirements. the present research, of nitrogen fixation in such an ecosystem, studied a salt marsh cord grass, Spartina alterniflora. The grass roots fix nitrogen at high rates and the bacterial symbiont in the root is similar to that of Digitaria (crab grass). These studies, in the Great Sippewissett Marsh on Cape Cod in Massachusetts, found that in plots fertilized with sewage sludge and in plots fertilized only with nitrogen, marsh grass grew taller, looked greener, and was higher in nitrogen. There was no change in plots fertilized only with phosphate. It was presumed that nitrogen fixation must be important in salt marshes. In fact fixation rates were very high. Several years of study have produced a better understanding of nitrogen fixation in salt marshes, with major fixation sites identified and seasonal rates and environmental factors determining those rates determined.

953. Van Raalte, C. D., I. Valiela, and J. M. Teal. 1976. The Effect of Fertilization on the Species Composition of Salt Marsh Diatoms. Water Research 10(1):1-4.

The diversity of epibenthic diatoms in a salt marsh is reduced by fertilization with either sewage sludge or urea. Counts of 500 individuals are sufficient to demonstrate a lower total number in the fertilized areas as compared with that of controls. Navicula salinarum Grun., which formed 5-9% of the diatoms in the controls, become dominant in fertilized plots, constituting 20-25% of the population. (EL)

954. Vaughn, J. M., and J. H. Ryther. 1974. Bacteriophage survival patterns in a Tertiary Sewage Treatment-aquaculture Model System. Aquaculture 4(4): 399-407.

Virus survival is investigated under simulated conditions of a tertiary sewage treatment-aquaculture system using a bacteriophage indicator. Survival time extends in a pure culture growing algae despite environmental conditions usually considered antiviral in nature. Survival is further enhanced by increasing the concentration of sewage effluent in the sewage-sea-water mixtures. (EL)

955. Veber, K., J. Zahradnik, and I. Breyl. 1980. Efficiency and Rate of Elimination of Polychlorinated Biphenyls from Wastewaters by Means of Algae. Bulletin of Environmental Contamination and Toxicology 25(6):841-845.

Polychlorinated biphenyls (PCB) were eliminated from municipal waste water and piggery waste water at efficiencies of up to 100% by algal concentration and subsequent lyophilization. Seenedesmus acutus was cultivated outdoors in southern Bohemia for 2-week periods during June-September 1978, at average daily temperatures of 19.8 C. Once a day a volume of the suspension was withdrawn and replaced by the same volume of wastewater. Dilution rates and corresponding elimination efficiencies were as follows: 0.1, 100%; 0.2, 67%; 0.3, 80%; and 0.5, 45%. Similar studies done with *Chlamydomonas geitleri* at an average temperature of 17.8 C in May and June 1979 showed 0.1, 84%; 0.2, 73%; 0.3, 64%; and 0.5, 100%. Although there was a trend toward decreasing efficiency of PCB absorption with increasing dilution rate, weather may also have been a factor. The PCB contents of the dry algal biomass at the maximum dilution rate were 213 mg per kg for *S. acutus* and 157 mg per kg for *C. geitleri*. (WR)

956. Vennes, J. W. 1970. Microbiology of Sewage Lagoons - Role of Purple Sulfur Bacteria in the Stabilization of Industrial Wastes. Tech. Completion Rept. North Dakota Water Resources Research Inst., Fargo, ND. 21 pp.

Ecologic relationships among various lagoon organisms and chemical and physical parameters of the lagoon were attempted. Pure cultures of the purple sulfur bacteria, *Chromatium vinosum* and *Thiocapsa floridana* were characterized with respect to optimum pH, temperature, and a variety of organic substrates. Experimental and actual lagoon substrate determinations suggest that the purple sulfur bacteria are predominantly responsible for the utilization of volatile fatty acids from the lagoon. Furthermore, the majority of the BOD in the lagoon may be attributed to these volatile acids. A variety of microbial and chemical determinations were made. (AA)

957. Vennes, J. W., H. W. Holm, M. W. Wentz, K. L. Hanson, and J. M. Granum. 1969. Microbiology of Sewage Lagoons - Effects of Industrial Wastes on Lagoon Ecology. Tech. Completion Rept. Univ. of North Dakota. Grand Forks, ND.

The report presents some of the ecological changes occurring in sewage lagoons receiving domestic wastes plus potato processing wastes (Grafton); cheese manufacturing wastes (Lakota); and domestic wastes (Harvey). Since each lagoon presents unique operating conditions, the results are summarized in topical form. (AA)

958. Verduin, J. 1969. Man's Influence on Lake Erie. The Ohio Journal of Science. 69(2):65-69.

Conversion of northwestern Ohio's great Black Swamp to farm land during the last half of the 19th century had a profound, but scantily documented influence on Lake Erie. Silts, once largely filtered by swampland vegetation, were, with the destruction of that vegetation, carried into Lake Erie, reducing light penetration and significantly altering the lake's biota. More recently enhancement of plant nutrients, especially phosphorus, which has increased 5-fold since 1948, has supported nuisance levels of plant growth creating severe oxygen depletion near the lake bottom and responsible for additional major and undesirable changes in species composition of plant and animal communities. The solution to this problem is removal of plant nutrients from the waters before they enter Lake Erie. The 'Living Filter' treatment, in which sewage plant effluents are filtered through root zones of plant communities, seems most promising. This treatment effectively removes nutrients, converting them to plant products. Another model, where effluent from sewage treatment plants is passed through a series of artificial lakes, processes the effluents effectively so that final-stage lakes are excellent recreational facilities, and the released waters do not burden aquatic environments.

959. Verry, E. S. 1979. Plant Nutrient Retention in Natural Bogs and Implications for Sewage Application. In J. C. Sutherland and R. H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of conference held 10-12 July 1979 at Higgins Lake, MI.

An undisturbed 9.72 ha watershed in north central Minnesota having two-thirds upland till soils with mature aspen and one-third sphagnum (3.24 ha) with mature black spruce was intensely instrumented to measure water-borne nutrient flow. We wanted to find out how the peatland portion retained natural inputs of N, P, K, Ca, and Mg resulting from direct precipitation and flows from the surrounding upland. Seasonal effects were measured during 3 years (1971-1973) using three natural periods for input; 1) spring (mid Nov. - mid May), 2) summer (mid May - mid Sept.), and 3) fall (mid Sept. - mid Nov.). Output periods were similar except for "fall" when streamflow sometimes extended to mid-Jan. Natural nutrient retention properties can help guide the timing of sewage effluent application.

The peatland received nutrients in direct proportion to the amount of precipitation plus upland flow and passed on nutrients in direct proportion to the amount of streamflow leaving it. In almost all situations the peatland retained a portion of the nutrients that entered it. However, retention was not related to water amounts, but rather to unknown processes.

We thought that spring rain and snowmelt might result in greater relative flushing rather than retention, but the opposite occurred. Generally the highest relative retention and the highest absolute retention were in the spring. We also plotted the absolute nutrient amount retained during each season over the amount received and found that retention, for all nutrients, increased as more was received. Thus, under natural ranges, the peatland was never saturated with nutrients.

These data indicate that effluent application need not be delayed until well after snowmelt because relative retention is highest during snowmelt runoff. This phenomenon may be related to luxurious sphagnum growth immediately after snowmelt and chemical adsorption. Also, natural processes exist for retaining increased nutrient loads. Thus, effluent research should define the range of loadings necessary to reach saturation so that criteria matching land area or outflow water quality to loading are possible. (AA)

960. Wagner, D.D. 1973. An Investigation of the Physical Impact of Sewage Outflow on a River-Estuarine Environment. Trident Scholar Project Rept. No. 50. U.S. Naval Academy. Annapolis, MD.

The impact of the sewage outflow from the treatment plant in Annapolis, Eastport, Maryland, into the Severn River is explored. A buoyant plume model of the behavior of the sewage upon introduction to the receiving water is presented which indicates dilution to a 3% sewage concentration by the time the waste reaches the surface. Bottom currents are investigated and compared with surface flows to assess their effect on dispersion of the contaminants. Finally, a tidal flushing model is constructed that predicts a uniform sewage pollution excess over the conditions of the Chesapeake Bay of approximately .05% throughout the Severn River. The effects of various environmental changes on the system are discussed as predicted by modification of the numerical model. Under present circumstances, no detrimental physical impact on the environment can be shown to exist. (AA)

961. Walker, M., and A. T. Ingham. 1980. Alternative Systems for Wastewater Management. Compost Science/Land Utilization 21(6):31-33.

Three promising alternatives to the construction of conventional gravity sewers are proposed for rural communities. These systems are intended to reduce the cost of sewage collection in these locations. The design and operation of the vacuum sewer, pressure sewer, and small diameter gravity sewer are described. Options for the treatment and disposal of collected sewage include sand filters, lagoons, aquaculture marsh systems, overland flow, and other land treatment alternatives. Management considerations for these systems are surveyed. (EL)

962. Walker, W. R., and W. E. Cox. 1974. Wastewater Irrigation: Its Legal Impact. Water Spectrum 6(2):15-22.

EPA is encouraged by the Federal Water Pollution Control Act Amendments of 1972 to develop revenue-producing waste treatment facilities: specifically, recycling potential sewage pollutions in connection with agriculture, silviculture, or aquaculture. The land use, groundwater, and surface water rights connected with wastewater irrigation at the state and municipal levels are explained. The ultimate test of feasibility for a given wastewater irrigation installation may well depend on legal constraints. (EL)

963. Walsh, G. E., L. H. Bahner, and W. B. Horning. 1980. Toxicity of Textile Mill Effluents to Freshwater and Estuarine Algae, Crustaceans, and Fishes. Environmental Pollution; Series A: Ecological and Biological 21(3):169-179.

The toxicity of secondary waste effluents from textile manufacturing plants was determined with freshwater (algae-*Selenastrum capricornutum*, crustacean-*Daphnia pulex*, minnow-*pimephales promelus*) and estuarine (algae-*Skeletonema costatum*, shrimp-*Palaemonetes pugio*, minnows-*Cyprinodon variegatus*) organisms. *D. Pulex* was generally the most sensitive animal, but no animal responded to all wastes. Growth of the algae S. capricornutum and S. costatum was affected by all wastes, through either inhibition or stimulation. Some wastes were stimulatory to S. costatum at low concentrations (i.e., less than 1%) but inhibitory at high concentrations (i.e., greater than 50%). The concentration of waste that stimulated growth of S. costatum by 20% compared with controls (SC20) was calculated and used with EC50 values for the survival of D. pulex to estimate the potential impact of the wastes in relation to volume of discharge. (PA)

964. Walters, A.M., R.O. Teskey, and T.M. Hinckley. 1980. Impact of Water Level Changes on Woody Riparian and Wetland Communities. Vol VII: Mediterranean Region Western Arid and Semi-Aird Region. FWS/OBS-78/93. U.S. Fish and Wildlife Service.

This volume covers the important woody plant species in the Mediterranean, Western Arid and Semi-arid Regions. These regions cover Arizona, New Mexico, California, Utah, Nevada, southern Idaho, eastern Washington and Oregon. This discussion centers primarily on the lower elevations of these states, while the mountainous areas of the western states will be discussed in a subsequent volume.

This review attempts to synthesize existing information on the effect of water level changes on woody plants found in riparian and wetland communities. In addition, the effect of drought on woody plants of these regions is described. Riparian vegetation is normally exposed to high groundwater levels as well as to periods of excess water due to flooding. The effect of excess water often causes stress to the plant resulting in decreased growth or even death. A plant's response to flooded conditions depends on many factors, including the species tolerance, water level, duration of flooding and time of year. Available information for individual species of the region has been listed in a tabular format.

In this arid region of the United Sttes the majority of precipitation falls in the dormant season, thus flooding effects are not as prominant as in other sections of the United States. Drought and the plant's resistance to drought are also important factors to consider. Therefore, a table of species responses to drought for these regions has been included.

965. Wanielista, M P., and W. W. Eckenfelder, Jr. (eds.) 1978. Advances in Water and Wastewater Treatment-Biological Nutrient Removal. Papers presented in part at a conference on biological nutrient removal alternatives held at Orlando, Florida, March 1978.

This book presents the state-of-the-art of biological nutrient removal alternatives by incorporating the results of recent research with design and operational details. The 13 papers discuss the fundamentals of process selection, N control processes, the kinetics of N removal, carousel activated sludge, 3 stage processing in nutrient removal, the Bardenpho process, the Phostrip system for removing P from wastewater, the use of water hyacinths in wastewater treatment, the use of cypress swamps in nutrient removal and wastewater recycling, biological fluidized beds, biological nutrient removal sludge processing, wastewater treatment cost effect and rotating biological contractors. Tables, diagrams, photographs, and a subject index complement the text. Individual papers are indexed in bioresearch index. (BA)

966. Water Films. Affluent Effluent: New Choices in Wastewater Treatment. Watertown, MA. A 40-minute film on wastewater treatment issues and options. The film looks at the practical and creative wastewater treatment systems of 17 communities across the country. Water Films 30 Bates Road, Watertown, MA.

967. Webster, B. 1975. Bulrushes Being Used in Artificial Marshes to Filter Water. New York Times. March 9, 1975. p. 47.

Bulrushes are being used in artificial marshes to screen out bacteria and chemicals that too often pollute much of the world's freshwater supply. The marsh water filtration method and other systems involving the use of aquatic plants and animals are being investigated as possible alternative, relatively inexpensive, ways of reclaiming wastewater. More than 1,000 such projects are being conducted in the U.S. alone, mostly by small communities, summer camps, and recreation areas. (EL)

968. Webster, L. F. 1974. Forging the Missing Link. Wat. and Pollut. Control 112(3):42-45.

The author discusses the possibility of using a closed system where the particular ecology would be self-supporting and -sustaining and include man, to treat organic wastes. Work being done at the Woods Hole Oceanographic Institute on a complex, multi-species food chain serving the dual function of a tertiary sewage treatment process, removing N and P before discharge into the ocean, and an aquaculture system producing a primary crop of shellfish, is described and the system flow-charted. The work carried out, and organisms used, to date are reviewed. It is calculated that a population of 50,000 would require 50 ha for algal farms and 1 ha for oyster production, compared to 40 ha, required by traditional land-disposal sewage treatment facilities. (AL)

969. WED Enterprises. 1976. Sewage Filtration and Energy Production in Using Water Hyacinths. EPCOT Tech. Meet. July 1, 1976. Walt Disney World, Orlando, FL.

970. Welch, E. B., and T. Lindell. 1980. Ecological Effects of Wastewater. Cambridge University Press, New York. 337 pp.

971. Weller, M. W. 1975. Studies of Cattail in Relation to Management for Marsh Wildlife. Iowa State Journal of Research 49(4):383-412.

972. Weller, M. W. 1978. Management of Freshwater Marshes for Wildlife, pp. 267-284. In R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater Wetlands: Ecological Process and Management Potential. Academic Press, Inc., New York.

Although commonly practiced on wildlife management areas, marsh management is poorly founded in theory and as a predictive science. Major objectives have been to preserve marshes in a natural state and to maintain their productivity. System or community-oriented management techniques are encouraged as most likely to meet diverse public needs, whereas species-specific management is more difficult, costly and limited in application.

The structure of a marsh is a product of basin shape, water regimes, cover--water interspersion, and plant species diversity. Resultant vegetative patterns strongly influence species composition and size of bird populations. Food resources influence mammals as well as birds. Species richness (i.e. number of species) may be the most simple index to habitat quality, although various diversity indices need further evaluation.

Marshes are in constant change, and wildlife species have evolved adaptations of wide tolerance or mobility. Throughout the Midwest, water levels and muskrats (Ondatra zibethicus) induce most vegetative change, and the pattern of vegetation, muskrat and avian responses are predictable in a general way. This short-term successional pattern in marshes forms a usable management strategy. Various ramifications are discussed that may enhance or perpetuate the most beneficial stages.

Artificial management practices are discouraged as costly and of short-term value whereas systems based on natural successional patterns produce the most ecologically and economically sound results. Public pressures for single-purpose management often increase as management potential increases, but such problems often can be avoided by advance planning and public relations.

Marsh management projects for wildlife have rarely been adequately evaluated because of cost, manpower, and inadequate experimental study areas. Some high priority, management-oriented research goals are suggested. (AA)

973. Weller, M. W., and L. H. Fredrickson. 1973. Avian Ecology of a Managed Glacial Marsh, pp. 269-291. In The Living Bird, Twelfth Annual, 1973, Cornell Laboratory of Ornithology, Ithica, NY.

974. Wellings, F. M. 1975. Interim Progress Report on Effect of Cypress Domes on Viruses in Effluent. In H. T. Odum, K. C. Ewel, J. W. Ordway, and M. K. Johnston (eds.), Cypress Wetlands for Water Management, Recycling and Conservation, Second Annual Report. Univ. of Florida, Gainesville.

975. Wellings, F.M. 1976. Viral Aspects of Wetland Disposal of Effluent. pp. 297-305. In: D.L. Tilton, R.H. Kadlec, and C.J. Richardson (eds.). Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

From a virological standpoint, the effluent from a cypress dome treatment plant serving a small trailer court is relatively comparable with that of urban treatment plant effluent. The quantities of virus entering the plants are comparable, but the variety of virus types entering the dome is limited. Since this dome represented a burned out dome, the efficacy of sewage treatment by an undisturbed cypress dome has not been tested.

976. Wellings, F.M. 1979. Technical Difficulties in Determining Virus Survival in Wetlands. In: J.C. Sutherland and R.H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a Conference held 10-12 July 1979.

All viruses which are replicated in the alimentary tract of man are discharged as an integral part of man's excrement. Over the past decade studies have shown that many of these viruses which enter the treatment plant are not inactivated but are discharged as infectious virus in the effluent and sludge. Because the viruses are solids-associated they are protected from many of the physiochemical, potentially virus inactivating processes encountered during passage through the treatment plant.

Although terminal chlorination inactivates some of the surviving virions, studies have domonstrated the presence of 100 to 750 plaque forming units (PFU) of virus per liter of chlorinated effluents. Determining the ultimate fate of these surviving virions in effluents discharged into wetlands is beset with technical problems, including the obtaining of a representative sample, elution and concentraion of the virus present and, finally, assay of the virus per se.

Based on the above considerations, there is little doubt that the presence of even one or two PFU of virus in any field sample must be considered significant since they would represent perhaps 1% to 10% of the total virus present. (AA)

977. Wellings, F. M., A. L. Lewis, and C. W. Mountain. 1974. Virus Survival Following Wastewater Spray Irrigation of Sandy Soils, pp. 253-260. In J. F. Malina, Jr. and B. P. Sagik (eds.), Virus Survival in Water and Wastewater Systems. Austin Center for Research in Water Resources.

978. Wellings, F. M. et al. 1975. Demonstration of Virus in Groundwater after Discharge Onto Soil. Applied Microbiology 29(6):751-757.

The survival of virus present in secondary effluents discharged into a cypress dome was studied. Isolations were made from concentrates of water drawn from 10-foot (304.80 cm) deep wells. Data presented show vertical and lateral virus movement as well as survival within the dome for 28 days during a period of heavy rains when no effluent was being applied. Due to the inefficiency of virus concentration procedures, it is proposed that much of the virus present was probably not demonstrated. A rapid, relatively inexpensive concentration technique for sewage influents and effluents is discussed. (AA)

979. Wenck, N.C. 1981. Wetlands and Organic Soils for the Control of Urban Stormwater, pp. 227-240. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

This paper consists of two major areas of interest. The first area is a review of a research project performed for the EPA to evaluate and assess urban runoff treatment methods using non-structural wetland treatment techniques. The second area will be to show examples of the application of the technology gained from the research. Five projects which are either constructed or in the design stage will be addressed. (AA)

980. Wentz, W. A. 1975. The Effects of Simulated Sewage Effluents on the Growth and Productivity of Peatland Plants. Ph.D. Diss. Univ. of Michigan, Ann Arbor. 112 pp.

This study was conducted on a north-central Michigan peatland to determine the effects of sewage effluents on the growth and productivity of several common peatland plants. Emphasis throughout these experiments was on practical application and the consequences of using the peatland as a disposal site.

Plants were subjected to varying levels of simulated sewage effluents in field and greenhouse experiments during both 1973 and 1974. Throughout the experiments information was collected on changes in aboveground and belowground standing crops, relative growth rates, net production rates, changes in nitrogen and phosphorus concentrations, specific leaf areas, leaf area index, and related parameters.

Although some changes in plant species composition and productivity are possible, it is unlikely that rapid or extensive degradation of the peatland will occur. It is possible that denitrification and phosphate adsorption onto the peat will have significant effects on the availability of plant nutrients. Assuming that sewage effluent will add nutrients at a rate approximately the same as that tested, it appears that the effluents will have no direct detrimental effects on most of the plants now present on the site.

981. Wentz, W. A., R. L. Smith, and J. A. Kadlec. 1974. A Selected Annotated Bibliography on Aquatic and Marsh Plants and Their Management. Publ. No. 2. Wetland Ecosystem Research Group, Univ. of Michigan, Ann Arbor.

982. Werblan, D., A. van der Valk, C. B. Davis, and R. J. Smith. 1979. Artificial Marshes as a Means of Treating Wastes From a Confined Swine Feeding Unit. In: J.C. Sutherland and R.H. Kadlec (eds.), Wetlands Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July, 1979. University of Michigan-Ann Arbor.

Eighteen "artificial marshes" (1.2 x 2.4 m plywood boxes filled with gravel) were constructed and planted with either cattail, burr reed, or common reed and loaded with one of 3 rates of liquid and solid swine manure. One objective was to examine plant viability under these abnormal nutrient loads; another objective was to evaluate these marshes as a manure renovation system in contrast to an anaerobic lagoon.

In treatments using solid manure, surface filtration alone removed approximately 600 g/m^2 wk of volatile solids, 200 g/m^2 wk of COD, 6 g/m^2 wk of and 2 g/m^2 wk of P. In all treatments, 50 g/m^2 wk of volatile solids and N, 100 g/m^2 wk of COD were removed by anaerobic filtration. Also, 3 g/m^2 wk of P was precipitated, adsorved onto gravel particles and incorporated by microorganisms; organic nitrogen was readily converted to NH_4 and 6 g/m^2 wk of N was removed by volatilization, gravel adsorption and microorganisms. Plant uptake of minerals and denitrification did not constitute major removal pathways.

Although the marshes were operated only from May to November, results indicate artificial marshes could be a desirable alternative to an anaerobic lagoon. The removals of COD (80-90%), volatile solids (50-90%), N (60%), and P (50%) in the artificial marshes were equivalent to removals in an anaerobic lagoon. Offensive odors were not produced and the lush vegetation (particularly that of cattail) attracted birds, amphibians, and small mammals. Insect problems were virtually eliminated by maintaining the water level at or below the gravel surface. Design modifications which might allow winter operations will be discussed. (AA)

983. Wert, F.S. and V.B. Henderson. 1978. Feed Fish Effluent and Reel in the Savings. Aquaculture Can be a Cost-Effective Wastewater Treatment Alternative. Water and Wastes Engineering 15(6):38.

984. Whaling, P.J., R.T. Barber, and J.C. Paul. 1977. The Distribution of Toxic Metals in Marine Ecosystems as a Result of Sewage Disposal and Natural Processes. North Carolina Water Resources Research Institute, Raleigh, NC. UNC-WRRI Rpt. No. 123. NTIS No. PB-272 644. March. 132 p.

Industrial discharge of wastes containing high concentrations of mercury and other toxic metals has largely been abated by strong federal and state regulation. The recovery of the polluted ecological systems is taking longer. Sewage treatment is a necessary part of our way of life and in addition, the natural accumulation of threatening levels of mercury and cadmium in unpolluted marine food chains is an aspect of environmental concern that must be understood to protect human health. The role of sewage disposal and natural food chain processes in the distribution of toxic metals in marine ecosystems was examined in several small eastern North Carolina estuaries receiving different inputs. On the basis of metal distribution, estuaries receiving treated sewage effluent were clearly distinguishable from those not receiving this discharge. The magnitude and spatial extent of the elevated toxic metal distributions was very limited in both sediments and organisms. While some organisms did not have ele- vated metal concentrations, the economically important oysters did not, nor did the marsh grass, Spartina alterniflora. The large and consistent variation in the amount of mercury and other trace metals discharged to the surrounding estuaries by various eastern North Carolina towns was traced to variations between the plants. It was not possible to account for the origin of the metal variations in wastewaters of these small towns which have no known commercial activities using these metals.

985. Wharton, C.H. 1970. The Southern River Swamp - A Multiple-Use Environment, Bureau of Business and Economic Research, Georgia State University, pp. 23-43.

The river-marsh ecosystem was studied to determine potential water cleansing abilities. Water quality data indicate that the Flint and Alcovy Rivers and their adjacent swamps apparently have the ability to filter pollutants from water. Swamp streams appeared to eliminate human waste and may have removed toxic pesticides. Swamps induced deposits of silt which may become useful to the biotic community. The swamp and its stream channel seemed intimately associated functionally, and appeared to form a natural hydrogeobiological water treatment system. The value of the cleansing action of 10 km of river and 251 ha of swamp was equivalent to sewage treatment for a city of 50,000. Potentially, the Alcovy River has three times this ability, worth $990,000/year. (AA)

986. Wharton, C. H., and H. P. Hopkins, Jr. 1980. In-Situ Evaluation of the Filtering Function of a Piedmont Creek Swamp. Rept. No. 2-80. Environmental Resources Center, Georgia Institute of Technology, Atlanta. 46 pp. (Available as NTIS Publ. No. PB 81-142234).

A small swamp in the northern piedmont region of Georgia was monitored from September 1976 to September 1978 to determine if swamps act as sinks for nutrients and trace metals. The total amounts of phosphorous, nitrates, ammonia, and several trace metals flowing into and out of the Cornish Creek Swamp were monitored during the two year period. This swamp was formed when a portion of the channelized Cornish Creek was filled up with sand and debris, and since the entrance and exit for this swamp is well-defined, we were able to establish the total amount of water moving through the swamp. This information, combined with the chemical analysis, allowed us to calculate the total amount of chemical nutrients and metals going into and out of the swamp over the two year period. The levels of phosphorous, nitrogen, and metals in the waters of the swamp indicate that it is pristine. Phosphorous was monitored in the form of orthophosphate and hydrolyzable phosphate; nitrogen was monitored as the ammonia and nitrate species. The metals: iron, magnesium, manganese, aluminum, sodium, and zinc were also monitored in the water. A small reduction in the total phosphate was observed after the water flowed through the swamp, but more nitrate left the swamp than entered it during the majority of the months in the study. Large quantities of ammonia were observed to leave the swamp during the spring months, but the swamp retained a small fraction of the amounts entering the swamp at other times. An abnormally high level of zinc reached the swamp during the period of study from an unknown source, but the swamp was effective in reducing the amount of zinc in the stream during this period. When phosphates and nitrates were added upstream from the swamp during the summer of 1978, the level of these in the water flowing through the swamp increased greatly. During the two day period of these experiments appreciable quantities of the nutrients remained in the swamp. (AA)

987. Wharton, C. H., H. T. Odum, K. Ewel, M. Duever, and A. Lugo. 1977. Forested Wetlands of Florida, Their Management and Use. Rept. to the Division of State Planning, Tallahassee, FL. Center for Wetlands, Univ. of Florida, Gainesville. 348 pp.

988. Whelan, T., J. T. Ishmael, and W. S. Bishop. 1976. Long-term Chemical Effects of Petroleum in South Louisiana Wetlands, Organic Carbon in Sediments and Waters. Marine Pollution Bulletin 7(8):

989. Whigham, D. F. 1979. Effects of Sewage Spray Irrigation on a Freshwater Wetland. I. Primary Production and Nutrient Standing Stocks. Presented at the Annual Meeting of the American Institute of Biological Sciences, held 12-17 August. Stillwater, OK.

1096. Whigham, D.F. In press.

990. Whigham, D. F., and S. Bayley. 1978. Nutrient Dynamics in Freshwater Wetlands, pp. 468-478. In P. E. Greeson, J. R. Clark, and J. E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding, Proceedings of the National Symposium on Wetlands, Lake Buena Vista, Florida. Tech. Publ. TPS 79-2. Amer. Water Resour. Assoc., Minneapolis, MN.

The purpose was to determine if definable trends appear when comparisons are made between the nutrient absorption capacities of various types of fresh water wetlands. The review showed that there are few data available for comparison, with the exception of N and P in above ground vegetation. Data from mass balance studies are almost nonexistent, which makes it impossible to determine the conditions necessary for specific types of wetlands to annually lose, gain, or be in balance with regard to nutrient fluxes. The only discernable trend was that wetlands with predominantly organic substrates accumulated less N and P in the above ground vegetation, yet the peat substrates seem to be capable of long-term storage of N and P. Recommendations for future research on nutrient dynamics in fresh water wetlands are discussed. (AA)

991. Whigham, D. F., J. McCormick, R. E. Good, and R. L. Simpson. 1978. Biomass and Primary Production in Freshwater Tidal Wetlands of the Middle Atlantic Coast, pp. 3-20. In R. E. Good, D. F. Whigham, and R. Simpson (eds.), Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, Inc., New York.

Although there are many measurements of peak standing crop and several estimates of aboveground annual net production, there are few accurate estimates of total net primary production for Middle Atlantic coastal freshwater tidal wetlands. Estimates of biomass and production vary widely and between vegetation types. The variability appears to be due to sampliilng techniques and/or the heterogeneous nature of freshwater tidal wetland vegetation. Undoubtedly, all estimates of primary production are low because they do not include data on growing season mortality of plants and plant parts, herbivore consumption, and belowground production. Most estimates of primary production are also low because freshwater tidal wetland communities undergo a series of physiognomic changes during the growing season and the measurements of primary production do not account for those seasonal patterns. Comparatively, freshwater macrophyte production in tidal wetlands appears to be at least equal to that of brackish water wetlands at the same geographic latitude. (AA)

992. Whigham, D. F., and R. L. Simpson. 1975. Ecological Studies of the Hamilton Marshes Progress Report for the Period June 1974 - January 1975. Rider College, Lawrenceville, NJ.

993. Whigham, D. F., and R. L. Simpson. 1976a. Sewage Spray Irrigation in a Delaware River Freshwater Tidal Marsh, pp. 119-144. In D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

High application rates of chlorinated effluent to a freshwater tidal marsh in New Jersey, caused changes in the vascular plant species composition of the wetland. Perennials have not been affected by the chlorine and clones at several species (sweet flag, cattial, rice, cut grass, arrow arum) have increased in aerial extent. Some annuals will decline in importance (touch-me-not, bur marigold) while others will increase (hallbeard tearthumb). Annual species composition can be regulated by controlling the spray regimes. Vascular plants acted as nutrient sinks during the summer and nutrients were released during the fall and winter with most of the nutrients being released within a month of the end of the growing season. There was also a noticeable increase in the amount and coverage of epibenthic algae.

994. Whigham, D. F., and R. L. Simpson. 1976b. The Potential Use of Freshwater Tidal Marshes in the Management of Water Quality in the Delaware River, pp. 173-186. In J. Tourbier and R. W. Pierson, Jr. (eds.). Biological Control of Water Pollution. Univ. of Pennsylvania Press, Philadelphia.

A summary of the studies concerning functional aspects of a freshwater tidal marsh and its potential use in water quality management. Research includes vegetation composition, primary production, soil algal distribution and biomass, soil nutrient and organic matter content, plant nutrient content, nutrient movement through marsh by surface water analysis, and movement of detritus in and out of marshes. The authors conclude that "high marsh areas may be acting as a nutrient sink during summer months and that perhaps the pond-like areas of the marsh may be playing a similar role in the winter...". "...it would appear that freshwater tidal marshes may also be capable of performing tertiary treatment." (WE)

995. Whigham, D. F., and R. L. Simpson. 1977. Growth, Mortality, and Biomass Partitioning in Freshwater Tidal Wetland Populations of Wild Rice (*Zizania aquatica* var. *aquatica*). Bull. Torrey Bot. Club. 104: 347-351.

996. Whigham, D. F., and R. L. Simpson. 1978. Nitrogen and Phosphorus Movement in a Freshwater Tidal Wetland Receiving Sewage Effluent, pp. 2189-2203. *In* Coastal Zone '78, the Proceedings of the Symposium on Technical, Environmental, Socioeconomic, and Regulatory Aspects of Coastal Zone Management. Am. Soc. Civil Engineers, New York.

Recent work on nutrients in tidal wetlands has led to the suggestion that they can be managed for treatment of sewage effluent. In this paper we report some results of a three year study on the effects of spraying chlorinated secondarily treated sewage effluent on a Delaware River freshwater tidal wetland near Trenton, New Jersey. Biomass and standing crops of N and P at the end of 1975 and 1976 growing seasons did not differ between experimental areas and control sites. The only consistent response of the aboveground vegetation was that plant material in areas receiving effluent had significantly greater %N and %P concentrations. Total N, %N, total P and %P of plant litter was significantly greater in the experimental areas. There were no significant substrate responses due to spray irrigation. Tide cycle studies showed that the irrigated wetland was a sink for N and an exporter of P. (AA)

997. Whigham, D. F., and R. L. Simpson. 1979. Effects of Sewage Spray Irrigation in a Freshwater Tidal Wetland. I. Primary production and Nutrient Standing Stocks. Presented at Annual Meeting Ecol. Soc. of America.

998. Whigham, D. F., R. L. Simpson, and K. Lee. 1980. The Effect of Sewage Effluent on the Structure and Function of a Freshwater Tidal Marsh Ecosystem. Tech. Completion Report to Office of Water Resources and Technology. Rider College, Laurenceville, NJ. 160 pp.

The effects of spraying chlorinated secondarily treated sewage on a Delaware River freshwater tidal wetland for three years was studied. Macrophyte net primary production was significantly lower in the experimental sites receiving sewage than in the no treatment controls in 1975 but not in 1976 or 1977. Diversity of annuals was reduced in the experimental sites largely due to the elimination of annuals. Although percent N and P were generally high in the vegetation of experimental sites, there was little difference in total N and total P between treatments and controls. Macrophyte decomposition rates were little affected by sewage application. Substrate N and P were not significantly different between sites, but surface litter of the experimental sites accumulated N and P. Epibenthic algae may contribute to this accumulation. Water quality studies showed the high marsh to be metabolically active. Tide cycle flux studies indicated that up to 40% of the N added to the wetland has assimilated during the late spring-early summer period. Conversely, there was a net loss of P from the wetland. These results are compared with those of similar studies in other wetlands. It is concluded that the strongly pulsed tidal regimes of the wetland, the low organic content substrate, and the eutrophic nature of the Delaware River waters contribute to the inability of the wetland to efficiently assimilate nutrients from sewage. (AA)

1097. Wile, I. et al. In press.

999. White, D. H., and M. T. Finley. 1978. Uptake and Retention of Dietary Cadmium in Mallard Ducks. Environmental Research 17:53-59.

Adult mallard ducks fed 0, 2, 20, or 200 ppm of cadmium chloride in the diet were sacrificed at 30-day intervals and tissues were analyzed for cadmium. No birds died during the study and body weights did not change. The liver and kidneys accumulated the highest levels of cadmium. Tissue residues were significantly correlated in all treatment groups and residues increased with treatment level. Hematocrits and hemoglobin concentrations were normal in all groups throughout the study. Little cadmium accumulated in eggs of laying hens, but egg production was suppressed in the group fed 200 ppm.

1000. White, D. H., M. T. Finley, and J. F. Ferrell. 1978. Histopathologic Effects of Dietary Cadmium on Kidneys and Testes of Mallard Ducks. Journal of Toxicology and Environmental Health 4:551-558.

Mallard ducks fed 2, 20, or 200 ppm cadmium chloride were sacrificed at 30, 60, and 90 d. No mortality occurred during the study and body weights remained unchanged. Kidney weights of the 200-ppm group were sigfnificantly greater after 60 and 90 d than those of controls; also, testis weights were significantly lower after 90 d. Kidneys of ducks fed 2 and 20 ppm cadmium were relatively unaffected; however, slight to severe kidney lesions were found in the 200-ppm group after 60 d of treatment. No significant lesions were found in mallard testes after feeding 2 ppm cadmium in the diet, and only a few birds in the 20-ppm group showed slight to moderate gonad alterations. After 90 d of treatment, however, testes of males fed 200 ppm had atrophied and the spermatogenic process had ceased. This study should provide important information for the interpretation of cadmium levels found in kidneys and testes of wild ducks. (AA)

1001. Whitton, B.A. 1971. Toxicity of Heavy Metals to Freshwater Algae: A Review, Phykos, 9, 1971, pp. 116-125.

This text provides a literature review on toxicity of heavy metals to freshwater algae. Emphasis was put on effects of exposure to heavy metals over long periods and adaptation potential of algae to heavy metals.

1002. Wikum, D., and M. Ondrus. 1980. The Drummond Bog Project-Growth of Selected Plant Species as a Function of Foliar and Peat Substrate Nutrient Concentrations. Report to the U.S. Forest Service. Univ. of Wisconsin, Stout. 38 pp.

The following results were reported on this wastewater treatment site in Wisconsin: 1) measurable increases in nutrient content of sediment over a one year period; 2) reduction in levels of ash and calcium in black spruce, labrador tea, and leatherleaf foliage; 3) no measurable damage to plant community during the study period; 4) measurable changes in peat and foliar levels of phosphorus, calcium, and ash content. The authors suggested that these parameters be measured during future research at the site. (EP)

1003. Wilcox, W. H. 1979. The Effect of Nitrogen and Phosphorus Enrichment on Salt Marsh Community Structure. Ph.D. Diss. Univ. of Tennessee. Nashville.

1004. Wile, I. 1980. An Experimental Approach to Wastewater Treatment Using Natural and Artificial Wetlands. Progress report, 27 October 1980. Ontario Ministry of the Environment, Ontario, Canada. 4 pp. plus attachment.

A natural marsh site located near the town of Bradford, Ontario, and a multicelled artificial marsh system near the town of Listowel, Ontario, are being assessed for their potential for year-round sewage treatment. The diked natural marsh has been monitored for background nutrient budgets for the last two years. The addition of partially treated wastes from the sewage treatment plant were scheduled to commence in 1981. The artificial marsh operations began in August 1980. The preliminary results obtained during the first 2 months of the latter operation and information on the design of the facility are included in this report. (EP)

1005. Wile, I., G. Palmateer, and G. Miller. 1981. Use of Artificial Wetlands for Wastewater Treatment, pp. 255-272. In: B. Richardson (ed.), Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board. St. Paul. 660 pp.

In Ontario, sewage lagoons are a common method for wastewater treatment in rural communtiies or small urban centers. However, receiving waters are frequently limited in their capacity to provide adequate dilution for the effluents, leading to proliferation of aquatic plants and fluctuating oxygen levels. The alternative approach of storing the wastes during periods of low flow is land consumptive, and mechanical systems are generally beyond the financial capabilities of small municipalities.

Since wetlands may provide a viable treatment alternative, an experimental study using an artificially constructed wetland was initiated in 1979. This study will attempt to define the degree of pretreatment required prior to waste discharge to the wetlands, loading rates, retention times and water depths for optimal operation of these types of systems.

The experimental facility consists of five separate systems and a small control marsh for monitoring rates of evapotranspiration. Construction of the marshes was completed in July 1980. Following planting with cattails, Typha spp., sewage additions were started in August 1980. Good nutrient removal rates were observed during the ice-free period, with total phosphorus concentrations of <0.2 mg 1^{-1} in the marsh effluents. Similarly, BOD and suspended solid loadings were reduced by more than 95% during passage through both marshes receiving raw aerated sewage or partially treated wastes from the existent east lagoon. During the winter period, the efficiency of the marsh sewage tretment systems declined substantially. Prior to the onset of winter, loadings of sewage influents to the marsh systems were more than doubled to avoid freezing in the pipes and outflow chambers. Concurrent with the increased flows, volumes within the marsh cells were reduced by ice formation, with resultant changes in retention times from approximately 8 days in the summer months to less than 3 days. These factors contributed to the reduced performance of the experimental marshes during the winter months. (AA)

1006. Williams, B., and M. B. Murdoch. 1969. The Potential Importance of Spartina alterniflora in Conveying Zinc, Manganese, and Iron into Estuarine Food Chains, pp. 431-439. In D. J. Nelson and J. C. Evans (eds.), Proc. 2nd Nat. Symp. Radioecology. NBS. Springfield, VA.

1007. Williams, T. C. 1976. The Feasibility, Planning, and Construction of Peatland Tertiary Treatment Systems, pp. 331-343. In D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of a National Symposium Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

The "feasibility" of adopting wetlands irrigation as an integral part of tertiary wastewater treatment involves finding satisfactory answers to the concerns of the local project Authority, the service area population, regulatory agencies, and scientific investigators. The concerns are for economy, effectiveness, environmental compatability, and aesthetics. Communication and publicity efforts have helped forge feelings of common interest and working together among the separate township governments in the Houghton Lake Area sewer Authority. The Houghton Lake Wetlands Study is a landmark in tertiary treatment, and in the future may rival upland irrigation in feasibility for rural and resort communities. (AA)

1008. Williams, T. C. 1979. The History and Development of the Houghton Lake Wetland Wastewater Treatment Project. In J. C. Sutherland, and R. H. Kadlec (eds.), Wetland Utilization for Management of Community Wastewater. Abstracts of a conference held 10-12 July 1979 at Higgins Lake, MI.

The Tri-Township wastewater treatment system serving the Houghton Lake, Michigan recreation area population of 15,000, consists of aeration-stabilization and storage ponds, and tertiary treatment provided by a natural peat wetland of 600 acres size. Completion of the wetland treatment facilities in early Summer 1978 was the final step in a 15-year effort. The wetland alternative for tertiary treatment represents savings in land and construction costs, relative to upland irrigation, of approximately $1,000,000. (AA)

1009. Williams, T. C. 1980. Wetland Irrigation Aids Nature and Man. Water and Wastes Engineering 17(11):28-31.

Two wetlands in Michigan (1 natural and 1 artificial) provide inexpensive tertiary treatment and benefit from the nutrients. The facility at Houghton Lake, Michigan, discharges to a natural 500 acre peat marsh. The wetlands irrigation system consists of gated, 12 in Al irrigation pipe, supported by a wooden, elevated walkway suspended on 2 in piling. The walk permits easy access for operation and maintenance. The system has been in full-scale operation for 2 irrigation seasons, each 4-6 mo long. During the summers of 1978 and 1979, an average of 85 million gal of effluent were applied to the 500 acre marsh. The wastewater contains 4 mg/l P, 0.6 mg/l NH_3-N, and 5.4 mg/l NO_3-N. A high level of treatment is achieved with minimal impact on the marsh. The system at Vermontville, Michigan, has developed an artificial wetland. Treatment facilities were completed in 1972 and have a capacity of 0.30 mgd. The system consists of 2 facultative ponds and 4 food irrigation fields located on the hill next to a small tributary to the Thornapple River. The Vermontville system presents excellent opportunities for the preservation of plant and wildlife. (PA)

1010. Williams, T. C., and J. C. Sutherland. 1979. Engineering, energy, and Effectiveness Features of Michigan Wetland Tertiary Wastewater Treatment Systems, pp. 141-173. In R. K. Bastian, and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC.

The results of two studies done on different wetlands in Michigan that receive secondary treated, non-chlorinated wastewater are summarized in this report. Both operations, one located at Vermontville and the other at Houghton Lake, have resulted in the effective removal of 98% to 100% of phosphorus through contact with reactive soils. The operation and maintenance, design, and capital and land costs are compared for these systems. The Vermontville site (11.5 acres) has flood irrigation fields that have overgrown with volunteer wetland vegetation (mainly cattails). The Houghton Lake site is a natural peat wetland approximately 600 acres in size. (EP)

1011. Williams, T. C., and J. C. Sutherland. Technical Aspects of the Tri-township (Houghton Lake, Michigan) Peat Wetland Tertiary Treatment System. Presented at the Water Pollution Control Federation Conference (Session 44), 11 October 1979, Houston, TX. 15 pp.

1012. Williams and Works, Inc. 1978. Operation and Maintenance Manual. Houghton Lake Sewer Authority, Houghton Lake, MI.

1013. William and Works, Inc. 1979. Reuse of Municipal Wastewater by Volunteer Freshwater Wetlands. Interim Report. William and Works, Inc. Grand Rapids, MI. 121 pp.

1014. Windom, H.L. 1977. Ability of Salt Marshes to Remove Nutrients and Heavy Metals from Dredged Material Disposal Area Effluents. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Tech. Rpt. D-77-37. December. 100 p.

Experimental raceways were constructed in a salt marsh adjacent to a dredged material confinement area to evaluate use of this environment as an overland flow advanced treatment system for effluent resultilng from dredged material disposal. The program was designed to determine the ability of salt marsh systems to remove nitrogen, phosphorus, iron, manganese, cadmium, copper, nickel and zinc from effluent. Application rates varied between 0.06 and 3.7 acre inches per day and concentrations of the contaminants were determined in the effluent from the disposal area and dishcarge from the explerimental system. All contaminants were found to decrease in the effluent as it passed through the experimental raceways. Removal efficiencies for nitrogen and phosphorus varied up to 50 and 70 percent, respectively. Mean metal removal efficiencies ranged between 15 and 32 percent. Efficiency of removal appeared unrelated to application rate but did appear to increase with concentration. Contaminants accumulated to sediments with only minor increases in salt marsh vegetation. Although results indicate nutrients and heavy metal concentrations in effluents from dredged material disposal areas can be reduced during passage through a salt marsh, conclusions about efficiency or removal may be influenced by the size of the experimental system used.

1015. Witter, J. A., and S. Croson. 1976. Insects and Wetlands, pp. 271-295. In D. L. Tilton, R. H. Kadlec, and C. J. Richardson (eds.), Proceedings of a National Symposium on Freshwater Wetlands and Sewage Effluent Disposal. Univ. of Michigan, Ann Arbor.

An exploratory study of insect fauna in Houghton Lake Marsh, Michigan, conducted in 1973 is summarized in this report. Other contents include a short literature review of other faunistic studies in wetlands, a review of the objectives of various insect sampling programs, a comparison of relative and absolute sampling techniques, and a discussion of criteria to be used when selecting insects as indicator species. Critical areas and principles in insect-wetland interactions are addressed. It is recommended that further long-term studies be conducted. (EP)

1016. Wolverton, B. C. 1975a. Aquatic Plants for Removal of Mevinphos from the Aquatic Environment. NTIS Report N75-16206.

Fragrant waterlily, joint-grass, and rush were used to assess the effectiveness of vascular aquatic plants in removing the insecticide Mevinphos from contaminated waters. The emersed aquatic plants waterlily and joint-grass succeeded in removing 87 and 93 ppm of mevinphos from water test systems in less than two weeks without apparent damage to the plants. Rush, a submerged plant, removed less--it still contained toxic levels of this insecticide after 35 days. (DM)

1017. Wolverton, B. C. 1975b. Water Hyacinths for Removal of Cadmium and Nickel from Polluted Waters. National Aeronautics and Space Administration. Tech. Memorandum X-72721. National Space Tech. Laboratory, Bay St. Louis, MS.

1018. Wolverton, B. C. 1979. Engineering Design Data for Small Vascular Aquatic Plant Wastewater Treatment Systems, pp. 179-192. In R. K. Bastian, and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. U. S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC.

1019. Wolverton, B. C. 1981. Hybrid Wastewater Treatment System Using Anaerobic microorganisms and reed (Phragmites communis). National Aeronautics and Space Administration. Tech. Memorandum TM-X-72739.

A small hybrid wastewater treatment system consisting of a settling tank in series with an anaerobic filter-reed (Phragmites communis) treatment cell was evaluated and compared with a similar plant-free system. Data demonstrated that by combining anaerobic filters, also referred to as attached film filters, and vascular aquatic plants a synergistic effect is produced which increases the treatment efficiency of each individual system. The plant-free system reduced the BOD_5 from 114 to 31 mg/l in 6 hours as compared to a reduction of 110 to 9 mg/l in the anaerobic filter-reed system in the same length of time. The BOD_5 and TSS after 24 hours in each component of the plant-free system was reduced from 114 to 14 mg/l and 51 to 15 mg/l, respectively. Under the same conditions, the hybrid system reduced the BOD_5 from 110 to 3 mg/l and the TSS from 68 to 6 mg/l. The hybrid system also reduced the total kjeldahl nitrogen (TKN) from 16.1 to 2.9 mg/l, total phosphorous (TP) from 4.4 to 2.0 mg/l, and the ammonia (NH_3-N) from 12.4 to 0.6 mg/l after 24 hours of exposure while the plant-free system demonstrated insignificant reduction of these components. (AA)

1020. Wolverton, B.C., R.M. Barlow and R.C. McDonald. 1975. Application of Vascular Aquatic Plants for Pollution Removal, Energy, and Food Production in a Biological System. NASA. NSTL. Bay St. Louis, MS.

Vascular aquatic plants such as water hyacinths (*Eichhornia crassipes*) (Mart.) Solms and alligator weeds (*Alternanthera philoxeroides*) (Mart.) Griesb., when utilized in a controlled biological system (including a regular program of harvesting to achieve maximum growth and pollution removal efficiency) may represent a remarkably efficient and inexpensive filtration and disposal system for toxic materials and sewage released into waters near urban and industrial areas. The harvested and processed plant materials are sources of energy, fertilizer, animal feed, and human food. Such a system has industrial, municipal, and agricultural applications. (AA)

1021. Wolverton, B. C., R. M. Barlow, and R. C. McDonald. 1976. Application of Vascular Aquatic Plants for Pollution Removal, Energy, and Food Production in a Biological System, pp. 141-149. *In* J. Tourbier and R. W. Pierson, Jr. (eds.), Biological Control of Water Pollution. Univ. of Pennsylvania Press, Philadephia.

This article describes the potential applications for wetlands as wastewater treatment systems. A one acre water hyacinth wetland can remove N and P from sewage effluent, then be harvested to yield bio-gas and fertilizer. Removal of pollutants such as phenol and heavy metals is possible also. The water hyacinth has potential as a food source for cattle, and even for man. (WE)

1022. Wolverton, B. C., and D. D. Harrison. 1974. Aquatic Plants for Removal of Mevinphos From the Aquatic Environment. J. Miss. Acad. Sci., 19:84-88.

1023. Wolverton, B. C., and R. C. McDonald. 1975a. Water Hyacinths and Alligator Weeds for Removal of Lead and Mercury from Polluted Waters. National Aeronautics and Space Administration. Tech. Memorandum X-72723, National Space Tech. Laboratory, Bay St. Louis, MS.

1024. Wolverton, B. C., and R. C. McDonald. 1975b. Water Hyacinths and Alligator Weeds for Removal of Silver, Cobalt, and Strontium from Polluted Waters. National Aeronautics and Space Administration. Tech. Memorandum X-72727, National Space Tech. Laboratory, Bay St. Louis, MS.

1025. Wolverton, B. C., and R. C. McDonald. 1975c. Water Hyacinths for Upgrading Sewage Lagoons to Meet Advanced Wastewater Treatment Standards: Part I. Tech. Memo. TM-X-72729. National Aeronautics and Space Administration, National Space Technology Laboratories, Bay St. Louis, MS.

Water hyacinths were studied as a means of accomplishing final filtration to remove nutrients, heavy metals, and other chemicals from domestic wastewaters. Biweekly grab samples from before and after saturating a secondary domestic sewage lagoon were compared with samples from a control lagoon free of water hyacinths. The water hyacinth-covered lagoon had a surface area of 0.70 acre with a total capacity of 1.5 million gallons, receiving an inflow of 115,000 gallons per day from a 3.8 acre aerated primary sewage lagoon. Retention times varied between 14 and 21 days depending on the water hyacinth evapotranspiration rates. The water hyacinths functioned as an efficient and inexpensive final filtration system in a secondary domestic sewage lagoon during a three month test period. They reduced the suspended solids, biochemical oxygen demanding substances, and other chemical parameters to levels below the state standards. While absorbing organics, nutrients, and other chemical elements from sewage waste, they produced large quantities of plant material. When grown in enriched sewage waste free of heavy metals, this biomass can be harvested and possibly processed into valuable feed products, organic fertilizer and soil conditioner, or methane gas and inorganic fertilizer. The volume of water hyacinths required depends onthe amount of sewage to be processes and the desired purity of the final wastewater.

1026. Wolverton, B. C., and R. C. McDonald. 1976a. Don't Waste Waterweeds. New Scientist 67:318-320.

Experiments conducted by the National Aeronautics and Space Administration indicate that water hyacinths (Eichhornia crassipes) have the ability to absorb organics, heavy metals, nutrients, and other chemical elements from wastewater under tropical and subtropical conditions while producing a large quantity of plant material. This water hyacinth biomass, when grown in sewage free of toxic metals, is a potential source of protein fertilizer, methane gas, and other valuable products. Currently, a water hyacinth chemical waste filtration system consisting of a zig-zag canal 330 meters long, 6.4 meters wide, and 0.8 meters deep is treating 95,000 liters/day of chemical and photo lab waste. On the basis of an analysis of raw sewage from small communities in South Mississippi, a half hectare lagoon covered with water hyacinths with a minimum sewage retention time of 2 weeks is estimated to be capable of purifying the daily wastes of 1000 people. An experimental water hyacinth lagoon has already reduced pollutant levels by 75-80%.

1027. Wolverton, B. C., and R. C. McDonald. 1976b. Water Hyacinths for Upgrading Sewage Lagoons to Meet Advanced Wastewater Treatment Standards: Part II. Tech. Memo. TM-X-72730. National Aeronautics and Space Administration, National Space Technology Laboratories, Bay St. Louis, MS.

Field tests using water hyacinths as biological filtration agents were conducted in the Missisippi Gulf Coast Region. The plants were installed in one single cell and one multiple cell sewage lagoon systems. Water hyacinths demonstrated the ability to maintain BOD_5 and total suspended solid (TSS) levels within the Environmental Protection Agency's (EPA) prescribed limits of 30 mg/l BOD_5 and 30 mg/l TSS.

A multiple cell sewage lagoon system consisting of two aerated and one water hyacinth covered cells connected in series demonstrated the ability to maintain BOD_5 and TSS levels below 30 mg/l year-round. A water hyacinth covered lagoon with a surface area of 0.28 hectare containing a total volume of 6.8 million liters demonstrated the capacity to treat 437,000 to 1,893,000 liters of sewage influent from 2.65 hectares of aerated lagoons daily and produce an effluent that met or exceeded standards year-round. (AA)

1028. Wolverton, B. C., and R. C. McDonald. 1976c. Water Hyacinths, *Eichhornia crassipes* (Mart.) solms, a Renewable Source of Energy. *In*: Capturing the Sun Through Bioconversion. Center for Metropolitan Studies. Washington, DC.

1029. Wolverton, B.C., and R.C. McDonald. 1976d. Water Hyacinths (*Eichhornia crassipes*) for Removing Chemical and Photographic Pollutants from Laboratory Wastewaters. Tech. Memo. TM-X-72731, National Aeronautics Space Administration, Bay St. Louis, MS. 10 pp.

1030. Wolverton, B.C., and R.C. McDonald. 1977a. Wastewater Treatment Utilizing Water Hyacinths *Eichhornia crassipes* (Mart.) solms, pp. 205-208. *In*: Proceedings of the 1977 National Conference on Treatment and Disposal of Industrial Wastewaters and Residues, Houston, TX.

1031. Wolverton, B. C., and R. McDonald. 1977b. Compiled Data on the Vascular Plant Program, 1975-1977. Rept. No. TM-79511. National Aeronautics and Space Administration. Bay St. Louis, MS. 149 pp.

The performance of a single cell, facultative sewage lagoon was significantly improved with the introduction of vascular aquatic plants. Water hyacinth (*Eichhornia crassipes*) was the dominant plant from April to November; duckweed (*Lemna* spp.) and (*Spirodela* spp.) flourished from December to March. This 2 ha lagoon received approximately 475 cu m/day of untreated sewage and has a variable COD, loading rate of 22-30 kg/ha/day. During the first 14 months of operation with aquatic plants, the average influent BOD, was reduced by 95% from 110 mg/l to an average of 5 mg/l in the effluent. The average influent suspended solids were reduced by 90% from 97 mg/l to 10 mg/l in the effluent. Significant reductions in nitrogen and phosphorus were affected. The monthly kjeldahl nitrogen for influent and effluent averaged 12.0 and 3.4 mg/l, respectively, a reduction of 72%. The total phosphorus was reduced on an average of 56% from 3.7 mg/l influent to 1.6 mg/l effluent. (NT)

1032. Wolverton, B. C., and R. C. McDonald. 1978a. Bioaccumulation and Detection of Trace Levels of Cadmium in Aquatic Systems by *Eichhornia crassipes*. Environmental Health Perspectives 27:161-164.

The water hyacinth (*Eichhornia crassipes*) may be used as a sensitive biological indicator for continuously trace quantities of toxic heavy metals in aquatic systems. A river water system polluted with Cd was simulated while other factors of temperature, day-night cycle, water quality, and light intensity remained constant. When the water hyacinth is maintained in river water containing 0.001 mg/l of cadmium chloride, the plant's root system will concentrate this element at an average rate of 0.9, 1.4, and 3.0 g Cd/g root dry weight after 24, 48, and 72 hr exposure periods, respectively. At a higher Cd concentration of 0.01 mg/l, Cd was concentrated in the roots much faster to levels of 6.8, 13.6, and 39.1 g/g root after 4, 8, and 24 hr exposure periods, respectively. At initial concentrations of 0.05 mg/l. Cd, the roots contained 29.5, 48.8, and 156 g/g root following 4, 8, and 24 hr exposure periods, respectively. During these same time intervals, the water hyacinth sorbed 56.7, 153, and 281 g/g root when the initial Cd concentration was increased to 0.10 mg/l.

The water hyacinth tops can also assist in the monitoring process when Cd contamination levels are 0.10 mg/l and greater. At this initial Cd concentration, Cd is translocated into the tops. After 8 hr, the tops averaged 1.1 g/g top. After 24 hr, this concentration was increased to 6.1 g/g top. (AA)

1033. Wolverton, B.C. and R.C. McDonald. 1978b. Nutritional Composition of Water Hyacinths Grown on Domestic Sewage. *In*: Compiled Data on the Vascular Aquatic Plant Program: 1975-1977. NASA. NSTL Station. MS

A nutrient analysis of water hyacinths grown in sewage wastewaters was conducted. Crude protein averaged 32.9% dry weight in the leaves, where it was most concentrated. The amino acid content of water hyacinth leaves was found to compare favorably with that of soybean and cottonseed meal. The vitamin and mineral content of dried water hyacinths met or exceeded the FAO recommended daily allowance, in many cases. It is concluded that in favorable climate zones, water hyacinths grown in enriched mediums, such as sewage lagoons, could potentially serve as a substantial dietary supplement or nutrient source. (AA)

1034. Wolverton, B.C. and R.C. McDonald. 1978c. Water Hyacinth Sorption Rates of Lead, Mercury, and Cadmium. NASA. NSTL. Bay St. Louis, MS.

Experiments were performed to test the ability of the water hyacinth (*Eichhornia crassipes*) to remove lead, cadmium and mercury from solution both individually and in combination. The plants were exposed to 10 ppm lead and one ppm each of cadmium and mercury for a period of 96 hours. The sorption of the heavy metals was monitored by periodic water sampling and plant tissue analysis at the termination of the experiment. Results indicated no significant interactive effect among the three metals tested. Within one hour, water hyacinths removed approximately 65 percent of the lead, 50 percent of the cadmium and 65 percent of the mercury, whether the plants were exposed to these metals individually or in combination. Almost all of the heavy metals were concentrated in the root tissue of the plants, although there was some translocation, particularly of cadmium, into the upper plant parts.

These results are discussed in the light of previous investigations. It is concluded that the water hyacinth could be useful both as an agent for reducing heavy metal pollution and as an indicator or monitor of chronic metal contamination of aquatic systems. (AA)

1035. Wolverton, B.C. and R.C. McDonald. 1978d. Upgrading Faculative Waste Stabilization Ponds with Vascular Aquatic Plants. In: Compiled Data on the Vascular Plant Program: 1975-1977. NASA. NSTL Station, MS.

The performance of a single cell, faculative sewage lagoon at NASA's National Space Technology Laboratories has been significantly improved with the introduction of vascular aquatic plants. Water hyacinth (Eichhornia crassipes) was the dominant plant from April to November; duckweed (Lemna spp.) and (Spirodela spp.) flourished from December to March. This 2 ha lagoon receives approximately 175 m^3/day of untreated sewage and has a variable BOD_5 loading rate of 22-30 kg/ha/day.

During the first 14 months of operation with aquatic plants, the average influent BOD_5 was reduced by 95% from 110 mg/l to an average of 5 mg/l in the effluent. The average influent suspended solids were reduced by 90% from 97 mg/l to 10 mg/l in the effluent.

Although this lagoon was not harvested at a rate necessary to achieve maximum nitrogen and phosphorus removal, significant reductions in both of these nutrients were effected. The monthly kjeldahl nitrogen for influent and effluent averaged 12.0 and 3.4 mg/l, respectively, a reduction of 72%. The total phosphorus was reduced on an average of 56% from 3.7 mg/l influent to 1.6 mg/l effluent. (AA)

1036. Wolverton, B. C., and R. C. McDonald. 1979a. Upgrading Facultative Wastewater Lagoons with Vascular Aquatic Plants. J. Water Pollut. Control Fed. 51(2):305-313.

The performance of a single-cell, faculative wastewater lagoon has been significantly improved with the introduction of vascular aquatic plants. Water hyacinth (Eichhornia crassipes) was the dominant plant from April to November; duckweed (Lemna and Spirodela spp.) flourished from December to March. This 2-ha lagoon received approximately 475 m^3/d of untreated wastewater and had a 5-day biochemical oxygen demand loading rate of 22 to 30 kg/ha d. During the first 14 months of operation with aquatic plants, the average influent 5-day biochemical oxygen demand was reduced by 95% from 110 mg/l to an average of 5 mg/l in the effluent. The average influent suspended solids were reduced by 90% from 97 mg/l to 10 mg/l in the influent. (AA)

1037. Wolverton, B.C., and R.C. McDonald. 1979b. The Water Hyacinth: From Prolific Pest to Potential Provider. Ambio 8(1):2-9.

The hardness and high productivity of the water hyacinth can be put to use in a controlled, freshwater environment to remove chemical pollutants from wastewater. In the process of absorbing minerals and nutrients from the water, the water hyacinth produces tremendous quantities of plant biomass which can be useful for feed, fertilizer or biogas. Great quantities of pure, fresh water can also be recovered from water hyacinth systems by covering them with greenhouses fitted with collection devices for capturing the water vapor that is normally lost through evapotranspiration.

At present, water hyacinth systems are limited to freshwater systems in warm climates. Floating greenhouses would be necessary to cover these systems if they were to be used in northern climates. Another possibility of harnessing nature to clean up polluted waters in northern climates would be to survey the freshwater aquatic plants native to these regions which possess many of the characteristics which make the water hyacinth a good biological agent for pollution removal. (AA)

1038. Wolverton, B.C. and R.C. McDonald. 1979c. Energy From Aquatic Plant Wastewater Systems. NASA. NSTL. Bay St. Louis, MS.

Water hyacinth (*Eichhornia crassipes*), duckweed (*Spirodela* sp. and *Lemna* sp.), water pennywort (*Hydrocotyle ranunculoides*), and kudzu (*Pueraria lobata*) were anaerobically fermented using an anaerobic filter technique that reduced the total digestion time from 90 days to an average of 23 days and produced 0.14-0.28 m^3 CH$_4$/kg (dry weight) (2.3-4.5 ft^3/lb) from mature filters. The anaerobic filter provided a large surface area for the anaerobic bacteria to establish and maintain an optimum balance of faculative, acid-forming, and methane-producing bacteria. Consequantly the efficiency of the process was greatly improved over prior batch fermentations. (AA)

1039. Wolverton, B. C., and R. C. McDonald. 1980. Water Hyacinth (*Eichhornia crassipes*) Productivity and Harvesting Studies. Economic Botany 34(1).

Water hyacinth growth rates were monitored from May through October in two sewage lagoons with different nutrient loading rates. The lagoon receiving the heaviest load sustained the highest average growth rates throughout the summer. The lightly loaded lagoon averaged a 29% increase in weight per week over the six month period with the highest growth rate occurring during June with an average weekly weight gain of 71%. The heavily loaded lagoon sustained an average growth rate of 46% per week for the same six month period with the highest measured growth rate of 73% increase in weight per week also occurring in June. In addition, the performance of three harvesters was evaluated. One harvester, consisting of a chopper and conveyor, was capable of picking up and chopping approximately 2.3 t of plants per hour and delivering them to a waiting truck. The second harvester was a single 1.52 m (5 ft) wide conveyor, and the third one was a modified clamshell bucket attached to a dragline. The average harvesting rate of each of these harvesters was approximately 9.3 t of water hyacinths per hour. (AA)

1040. Wolverton, B. C., and R. C. McDonald. 1981. Natural Processes for Treatment of Organic Chemical Waste. *In* Toxic and Hazardous Substances, a special publication of the Environmental Professional.

Anaerobic filters and combination anaerobic filter/vascular aquatic plant systems were used to remove and biologically degrade phenol and m-cresol from contaminated river water. The common reed (*Phragmites communis*) and cattail (*Typha latifolia*) were grown on top of two separate anaerobic filters. Starting with approximately 100 mg/l phenol solutions, the *P. communis*, *T. latifolia*, and plant-free anaerobic filter systems removed 93%, 83%, and 60%, respectively, of the phenol during the first 24 hours of exposure. The *P. communis* and plant-free anaerobic filters removed 69% and 58% of m-cresol from 100 mg/l solutions after 24 hours. The results indicated that the phenol and m-cresol were rapidly adsorbed on the filter surfaces and then assimilated and/or metabolized. Accurate determinations of the organics were made using gas chromatography. The corresponding TOC, BOD_5, and COD of each sample were also reported. (AA)

1041. Wolverton, B.C. and M.M. McKown. 1976. Water Hyacinths for Removal of Phenols from Polluted Waters. Aquatic Botany, 2(1):191-201.

A quantity of 2.75g dry weight of water hyacinth demonstrated the ability to absorb 100 mg. of phenol/72 hr from distilled water, river water, and bayou water. One ha of water hyacinth is potentially capable of removing 395 kg of phenol/72 hr from water polluted with this chemical. (AA)

1042. Wolverton, B.C., R.C. McDonald and J. Gordon. 1975a. Bio-Conversion of Water Hyacinths into Methane Gas: Part I. National Aeronautics and Space Adminstration Tech. Memorandum X-72725, Natl. Space Tech. Laboratory, Bay St. Louis, MS.

1043. Wolverton, B. C., R. C. McDonald, and J. Gordon. 1975b. Water Hyacinths and Alligator Weeds for Final Filtration of Sewage. Tech. Memo. TM-X-72724. National Aeronautics and Space Administration, National Space Technology Laboratories, Bay St. Louis, MS.

1044. Wondrausch, J. 1969. Phosphorus Sorption in Mucky-peat Soils. Polish J. Soil Sci. 11:997-106.

1045. Wood, D.K., and G. Tchobanoglous. 1976. Trace Elements in Biological Waste Treatment. J. Water Pollut. Control Fed. 74:1933-1945.

The importance of trace elements for microbial growth and metabolism is well recognized. However, their importance in the operation of biological waste treatment processes is not usually considered or understood fully. It is often assumed that the concentration of trace elements present in a wastewater will be sufficient for good treatment. This assumption may not be valid, because the types and concentrations of trace elements in a wastewater vary with location and time. Trace elements may also be removed from the wastewater by various means, including adsorption and hydrogen sulfide precipitation. For these reasons, trace element deficiencies may occur, and treatment problems, including the occurrence of filamentous organisms, may result. An argument supporting this thesis, along with an analysis of the role of trace elements in the activated sludge process, is presented. Recommendations and alternatives for overcoming problems that may be caused by trace element deficiencies are offered. (AA)

1046. Wood, J. M. 1974. Biological Cycles for Toxic Elements in the Environment. Science. 183:1049-1052.

In this article, the author describes some of the chemical and biochemical transformations of toxic elements in the environment, placing special emphasis on the role played by microorganisms. He also shows that our present knowledge of the biological cycles of toxic elements enables us to predict the behavior of other toxic elements in the environment. (AA)

1047. Woodwell, G., J. Ballard, J. Clinton, and E. Pecan. 1976. Nutrients, Toxins and Water in Terrestrial and Aquatic Ecosystems Treated with Sewage Plant Effluents. Brookhaven National Laboratory, Upton, NY.

The objective was to appraise the capacity of terrestrial and aquatic plant communities for absorbing and retaining nutrients and organic matter in sewage and for releasing 'clean' water. The results showed the following: (1) Under normal circumstances, without the addition of water or nutrients in sewage, the flux of nutrients into the groundwater was greatest under the agricultural communities and least under the late successional forest communities; (2) The highest concentrations of nutrients in the percolate of the untreated communities commonly occurred in the earliest stages of succession; (3) Treatment with sewage reduced the differences in concentration in the percolate between the communities of the sere; (4) Calculation of the budgets of the various ecosystems showed that the forested stages accumulated the largest fractions of the inputs; (5) Appreciable changes occurred in the quality of percolate under the controlled communities over the period of the experiment; and (6) Present indications are that if sewage-treatment systems using natural communities are to be devised, they will require combinations of aquatic and terrestrial systems.

1048. Woodwell, G. M. 1977. Recycling Sewage Through Plant Communities. Amer. Sci. 65:556-562.

Recent research indicates that aquatic systems, especially marshes and ponds used in combination with terrestrial systems that benefit from irrigation, can be used to manage sewage effectively and inexpensively. An area of 50 acres containing a marsh associated with a shallow pond approximately the same size could effectively handle sewage for 10,000 people. In light of the economic and health repercussions that result from the current uncontrolled use of large water bodies for waste disposal-the New York Bight, Puget Sound, the Charles River, etc. - the transition toward closed, controlled systems, despite the large areas and careful design required, appears necessary and economical. (EL)

1049. World Health Organization. 1973. Reuse of Effluents: Methods of Wastewater Treatment and Health Safeguards. Tech. Rept. Series No. 517. Geneva, Switzerland.

1050. Wynn, S. L. 1979. A Comparison of Data Collection and Methods Used to Monitor Impacts on Severely Disturbed Wetlands. Ph.D. Diss. Univ. of Wisconsin. Madison. 417 pp.

1051. Yip, S. W., and M. H. Wong. 1977. The Effects of Sewage Sludge on the Growth Rate of Carp, Cyprinus carpio L. Environ. Pollution 14(2): 127-132.

The optimal quantity of sludge for rearing fish was investigated in the laboratory, Cyprinus carpio L. was chosen because it is one of the principal species reared locally in Hong Kong, and because it is a detritus feeder. Carp reared in tap water to which sludge is added to give a concentration of 0.2%, or in sewage effluent, have higher growth rates than carp reared in tap water alone have. (EL)

1052. Yonika, D. A. 1979. Effectiveness of a Wetland in Eastern Massachusetts in Improvement of Municipal Wastewater, pp. 91-100. In R. K. Bastian, and S. C. Reed (eds.), Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 439/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division. Washington, DC.

The quality of water entering and leaving part of Great Meadows National Wildlife Refuge near Concord, Massachusetts, was studied. The refuge receives chlorinated secondary effluent. Nutrient removal efficiencies were measured over different seasons for each of the two wetland types present. Low removal rates of about 0.5 pounds per acre per day of N and P were measured. Removal rates were greatest during early spring, which corresponded to the period of most rapid vegetation growth. (EP)

1053. Yonika, D. A., and D. Lowry. 1978. Bi-monthly summary reports: November-December 1977; March-April 1978; May-June 1978; September-October 1978. IEP, Inc., Wayland, MA.

1054. Yonika, D., and D. Lowry. 1979. Feasibility Study of Wetland Disposal of Wastewater Treatment Plant Effluent. Final report to the Massachusetts Water Resources Commission, Division of Water Pollution Control. IEP, Inc., Wayland, MA. 134 pp. (plus operations manual and bibliography).

1055. Yonika, D., and D. Lowry. 1980. Wetland Disposal of Wastewater Treatment Plant Effluent. IEP, Inc., Wayland, Mass. October 24, 1977 to October 24, 1978.

1056. Yount, J.L. and R.A. Crossman, Jr. 1970. Eutrophication Control by Plant Harvesting. J. Water Poll. Contr. Fed. 41: 173-183.

1057. Zahradnik, J. W., L. S. Turner, H. L. Levine, and C. Tucker. 1976. Evaluation of Proposed Man-Made Ponds for Food Production to Recover Values in Waste Heat and Solid Organic Sludges. Publ. No. 65. Water Resources Research Center, Univ. of Massachusetts, Amherst. 64 pp.

An analysis was conducted to determine: (1) the potential value of using, simultaneously, thermal effluents and sewage sludges in aquatic cultures; (2) the technical and economic feasibility of utilizing multilevel aquatic cultures in the recovery of these wastes; and (3) data voids and uncertainties which are of importance in implementation of the system designed. System inputs, potential system outputs, and potential subsystem characteristics were characterized and documented through a literature survey. (NT)

1058. Zaim, M. and H.D. Newson, 1980. Effects of Wastewater Spray Irrigation on Indigenous Mosquito Populations. Environmental Entomology 9(5): 563-566.

1059. Zapatka, T.F., and R.W. Hann, Jr. 1976. Evaluation of Safety Factors with Respect to Ocean Disposal of Waste Materials. Sea Grant Publ. 77-202. Texas A&M University. College Station, TX. 105 pp.

Assessment of the risk and consequent environmental harm to the oceans is essential if ocean dumping is to be continued. The available literature, bioassay studies, and pertinent research concerning chronic effects and the risk they impose on the marine ecosystem was studied. The correlation between acute and chronic toxicities for known hazardous materials were investigated and defined. The variables defined to be of most importance are: stage of development, concentration of toxicant, time of exposure, specific or non-specific reactions, lifetime of the compound, reactions with other chemicals, and bioaccumulation. The ranges of ratios for different conditions and situations or at least the ratios of acute to chronic toxicities for various classes of materials were determined. (NT)

1060. Zeiders, K.E., 1975. *Stagonospora foliicola*, a Pathogen of Reed Canary Grass Spray-Irrigated with Municipal Sewage Effluent. Plant Dis. Rep. 59:779-783.

1061. Zeiders, K.E. and R.T. Sherwood. 1977. Effect of Irrigation with Sewage Wastewater, Cutting Management, and Genotype on Tawny Blotch of Reed Canary Grass. Crop Sci. 17:594-596.

1062. Zoltek, J., S. E. Bayley, F. L. Boyt. 1977. Removal of Nutrients from Treated Municipal Wastewater by Wetland Vegetation. J. Water Pollut. Control Fed. 49(5):789-799.

Secondary sewage effluent from Wildwood, Florida, is discharged to a mixed hardwood swamp, and studies have been carried out to assess the effectiveness of this method of disposal. The results, summarized in tables and graphs, indicate that this is a satisfactory alternative to tertiary treatment as regards removal of nutrients and bacteria, and the sewage effluent is, therefore, not a major contributor of pollution to Panasoffkee Lake, which is bordered by the swamp. The economic value of the swamp is estimated. (AL)

1063. Zoltek, J., Jr., S. E. Bayley, T. J. Dolan, A. J. Herman, D. A. Graetz, and N. L. Erickson. 1978. Removal of Nutrient from Treated Municipal Wastewater by Freshwater Marshes. Progress Report to the City of Clermont, FL. Center for Wetlands, Univ. of Florida, Gainesville. 297 pp.

1064. Zoltek, J., Jr., S. E. Bayley, A. J. Herman, L Tortora, and T. J. Dolan. 1979. Removal of Nutrients from Treated Municipal Wastewater by Freshwater Marshes. Final Rept. to the City of Clermont, FL. Center for Wetlands, Univ. of Florida, Gainesville. 325 pp.

1065. Zunarellilvandini, R. and A.M. Cognettivarriale. 1981. Effects of Wastewater Effluents on a Polychaete Community in Littoral Sandy Bottoms. Cahiers de Biologic Marine 22(2):123-131.

The most recent additions to the bibliography are located on the next pages. All new citations are alphabetized separately and numbered in sequence with the previous entries, beginning with number 1066. For the reader's convenience, these new entries have been inserted in proper alphabetical order into the main entries by author and date.

1066. Barten, J.M. 1983. Nutrient Removal from Urban Stormwater by Wetland Filtration: The Clear Lake Restoration Project. Presented at the Fourth Annual Meeting of the Society of Wetland Scientists. June 5-8, 1983. St. Paul, Minnesota.

Clear Lake is a 257 ha body of water located in southcentral Minnesota. It is a heavily utilized recreational lake which has become severely eutrophic due to the inflow of nutrient rich urban runoff from the adjacent City of Waseca, Minnesota. In 1981, 50% of the hydraulic load and 55% of the phosphorus load to the lake was diverted into a 21.4 ha peat marsh on the northwest corner of Clear Lake. A series of ditches and dikes were constructed in the marsh to retain stormwater until the phosphorus could be removed by percolation through the peat. The filtered water was then pumped into Clear Lake. The filtration system was designed to allow for harvesting of vegetation in the marsh to prevent saturation of the phosphorus adsorption sites in the peat. In 1981, 73.3 x $10^4 m^3$ of water were filtered through the system and 258.6 kg of phosphorus removed. In 1982, 89.6 x 10^4 m^3 of water were filtered and 526.7 kg of phosphorus removed. The primary phosphorus removal mechanisms were physical entrapment and plant uptake. The total quantity of phosphorus removed in 1982 amounts to 40% of the average annual load to Clear Lake. Mean orthophosphorus, total phosphorus and chlorophyll a concentrations in Clear Lake decreased significantly following diversion of stormwater to the marsh. (AA)

1067. Bastian, R.K. and J. Benforado. 1983. Waste Treatment: Doing What Comes Naturally. Technology Review 86(2):59-66. Feb. - March.

Wastewater and sludge are steadily growing in quantity and water pollution remains a serious national concern. These problems can be alleviated by viewing municipal wastewater and sludge as valuable resources. Many communities can handle their sewage more economically through reuse by adopting "natural" treatment systems.

The challenge is to learn how to manage natural ecosystems so that they can safely and effectively assimilate and recycle sewage wastes. Better understanding of natural ecosystem functions will lead to development of "artificial" natural systems that capitalize on the capabilities of these same processes.

A brief informational introduction is presented on the various methods of applying wastewater and sludge to land. Current examples of operating systems are presented as well as a short discussion of the advantages/disadvantages of each method.

Aquatic treatment systems are also discussed in the same format of background information, current examples in operation, and the relative attractiveness of this wastewater treatment method.

Federal policies regarding alternative and innovative technologies are discussed along with data on the Federal money available for such grants and the results of the past few years of alternative and innovative technology projects.

Wide spread acceptance of natural treatment systems can be achieved with more public education. Also needed for success are good project design and management, more research on long term impacts of contaminants in a natural system, and appropriate regulations and guidelines. Properly managed natural ecosystems, while no panaceas, do offer an ecologically acceptable way to deal with pressing water pollution problems at reasonable cost.

1068. Benforado, J. 1983. Wetlands for Wastewater Treatment. EPA Journal 9(2): 14-15.

1069. Black, S.A, I. Wile and G. Miller. 1981. Sewage Effluent Treatment in an Artificial Marshland. Presented at the 1981 Conference of the Water Pollution Control Federation. Detroit, Michigan. Oct. 4-9, 1981.

Sewage lagoons are a common means of wastewater treatment for smaller Ontario communities. Frequently, the capacity of receiving waters to accept effluent from such facilities is limited by inadequate dilution during summer low flow periods leading to nuisance proliferation of plants and algae, with attendant widely fluctuating oxygen levels. Storage of effluent during periods of low flow requires large areas of land, and replacement of lagoons with mechanical treatment systems is very costly for small municipalities. Natural or artificial marshlands may provide a viable treatment alternative.

To determine the potential of wetlands for year-round sewage treatment in Ontario, an experimental study using an artificial marsh was established in 1979. The study is designed to define the degree of pretreatment required prior to waste discharge to wetlands, maximum loading rates, required retention periods and depths of liquid to establish optimal operational limits for these types of systems.

The artificial marsh has been constructed at the site of the Listowel sewage lagoon which consists of an aeration cell and two lagoons operated in series. The channelized and open marshes are planted with cattails, *Typha* spp.

Each system is capable of operating at flow rates of 0.5 to 2 times average design and at various depths and retention times. Flows are controlled and measured by V-notch and rectangular weirs and water level recorders. Routine parameters (i.e. nutrients, BOD_5, etc.) are monitored on a weekly basis in all influent and effluent streams.

This paper presents data on the first full year's operation of the artificial marsh, including loadings, removal efficiencies and effluent qualities of the various systems.

Preliminary data suggest that artificial marshes have the capacity to improve the quality of partially treated wastewaters; the degree of improvement being dependent upon many factors including hydraulic loading, retention time, season and system configuration. (AA)

1070. Brennan, K.M. (ed.). 1981. The Effects of Wastewater Treatment Facilities on Wetlands in the Midwest. (Draft Technical Report). Prepared under contract to the U.S. Environmental Protection Agency, Region V, by WAPORA, Inc. (See also USEPA, 1983b, for final document.)

1071. Brennan, K.M., S.D. Bach and G.L. Seegert. In press. Effects of Wastewater on Wetland Animal Communities. *In* Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

Little is known of the effects of the discharge of treated municipal wastewater on the animal communities of freshwater wetland ecosystems. The addition of nutrients, suspended and dissolved solids, chlorine, heavy metals, and disease organisms and the alterations of flow periodicity and rate, water level, pH, and alkalinity constitute changes in environmental conditions that could result in a wide range of changes in communities of invertebrates, fish, and other wildlife (amphibians, reptiles, birds, and mammals). Because of the potential impact and the lack of direct knowledge of impacts, wetland use for wastewater treatment must be carefully considered. Most of the studies performed at wetland treatment sites have focused on changes in water quality, vegetation, and litter; the only studies of wildlife at natural wetlands have been performed in Florida, Michigan, and Wisconsin. Preliminary studies on wildlife have also been done at two volunteer wetlands in Michigan. Because so few studies have been done on the primarily terrestrial animals inhabiting wetland ecosystems which receive wastewater, the potential effects of wastewater application must be identified by inference from wildlife use of such treatment facilities as effluent lagoons, stabilization ponds, and old field or forest land irrigated with wastewater. On the positive side, the availability of nutrient-bearing water from a treatment facility constitutes a potential resource that could be used to restore or maintain a disturbed wetland, create an artificial wetland to provide additional habitat, or maintain a volunteer wetland (developed as a consequence of the growth of wetland plants in a flood irrigation field or in a terrestrial plant community through which a wetland discharge passes), and consequently, to increase the diversity of wildlife habitat. The known and anticipated effects of the discharge of treated municipal wastewater on the animal communities of freshwater wetland ecosystems are presented in this paper according to three groups of animals present in wetland ecosystems:

* Invertebrates
* Fish
* Wildlife (amphibians, reptiles, birds, and mammals).

Information in the literature about the effects of wastewater on each of these groups is summarized and the major types of impacts identified or postulated are presented in the form of impact factor trains. In these diagrams, changes in the physical and biological environment are indicated as potential causes of subsequent changes in the animal communities. Effects on animal health, including potential transmission of disease to humans, are mentioned briefly. The use of wastewater for enhancement of wildlife habitat is also discussed in the following paper. (AA)

1072. Gosselink, J.G., and L. Gosselink. In press. The Mississippi River Delta - A Natural Wastewater Treatment System. _In_ Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

Wetlands have been shown to have considerable potential for wastewater treatment, but in only a few cases has it been possible to monitor the long-term effect of high nutrient loading rates on wetland ecosystems (Kadlec and Kadlec 1979).

River deltas have evolved over millennia as the downstream receivers of runoff into rivers. Large rivers, especially, have high loading rates for sediments and sediment-related nutrients. The Mississippi River delta is the largest wastewater treatment system in the United States; it receives runoff from more than one-half of the U.S. land area. Historically, as urban and industrial growth has occurred, the Mississippi River has become the conduit for elimination of wastes from a million households and thousands of industrial plants.

The present day Mississippi River delta region is about 10,000 years old. Its sediments contain a record of nutrient deposition that goes back to the end of the last glaciation. The hydrogen bomb fallout product Celsium-137(^{137}Cs) has labelled the sediments and allows us to examine the last 30 years in detail. What can we learn from this record? Is the delta a useful analog for a municipal overland flow system? If it is, what are the long-term characteristics of the delta, and what conditions make its activity effective? To answer these questions, we examined the nutrient concentrations and loading rates of river water flowing into the delta, and the nutrient retention ability of several different kinds of delta environments. (AA)

1073. Grimes, D. In press. Microbiological Studies of Municipal Waste Release to Aquatic Environments. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a workshop, June 23-25, 1982. University of Massachusetts, Amherst MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

1074. Guntenspergen, G.R., and F. Stearns. In press. Ecological Perspectives on Wetland Systems. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

Wetlands have long been used as sites for domestic sewage discharge, but the studies needed for an ecosystem-based evaluation are few and recent (e.g., Boyt et.al. 1977); Ewel and Odum 1979; Tilton and Kadlec 1979; Valiela, this volume; Guntenspergen et.al. 1980; Mudroch and Capobianco 1979; Deghi et.al. 1980; Dolan et.al. 1981). To date, most wetland studies have emphasized water quality effects to the exclusion of other impacts. The major concern has been the ability of the wetlands to significantly improve the quality of the effluent being discharged. We believe that examination of the ecological impacts of wastewater application is essential and is long overdue. It is unrealistic to assume that there will be no ecological changes. In an earlier review (Guntenspergen and Stearns 1981), we concluded that biological changes are associated with nutrient addition to wetlands and that these changes are manifested at the ecosystem level. A number of studies have indicated that nutrient addition through effluent discharge enhanced biomass production and, at the same time, certain species were eliminated by alterations in the physical environment or by competition. (AA)

1075. Hammer, D.E. and R.H. Kadlec. 1983. Design Principles for Wetlands Treatment Systems. Project Summary. EPA-600/S2-83-026. Robert S. Kerr Environmental Research Laboratory. Ada, Oklahoma. May. (See also Hammer, D.E. et al., 1983 for complete version of this article.)

Published data pertaining to the treatment of wastewater by wetland irrigation have been assembled and analyzed to begin identifying general principles for the successful design of wetland facilities. Sources of operating data have been tabulated. Performance is roughly correlated with overall systems features, but cannot be predicted on the current basis. Existing compartmental models require more detailed information than does or will exist; thus a simplified compartment model is presented.

Water quality is controlled by rapid processes related to water movement, mass transport to other commpartments, and consumption kinetics. Thus, wetland hydrology is fundamental to the analysis of water quality improvement. The ultimate fate of nutrients and contaminants is determined by sedimentation, biomass production and harvest, soil and microbial processes. Required wetland area depends on effluent quality, ecosystem type and age, and hydraulic regime. These questions can be addressed in terms of a mass transport model for the zone of rapid removal and a "saturation" model for the expansion of a zone of stabilized activity about the discharge point. Material balances, considering only long-term consumption mechanisms for nutrients and other pollutants, determine the useful life and ultimate performance of a wetland system.

Operational techniques and the use of constructed wetlands are also considered. The economics of wetland treatment are discussed. (AA)

1076. Hammer, D.E. et.al. 1983. Design Principles for Wetland Treatment Systems. University of Michigan - Ann Arbor. National Technical Information Service No. PB83-188722. April. (See also Hammer, D.E. and R.H. Kadlec, 1983, for EPA Project Summary version of this article.)

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The selection of natural sites and the physical facilities associated with wetland treatment are discussed. A possible protocol for site review is presented. An appendix of existing wetland sites used for wastewater treatment is included. Operational techniques and the use of constructed wetlands are also considered. Finally, wastewater impacts on wetlands and the economics of wetland treatment are discussed. (AA)

1077. Heliotis, F.D. 1981. Wetland Systems for Wastewater Treatment: Operating Mechanisms and Implications for Design. University of Wisconsin-Madison. Master's Thesis. 103 p.

The goal of this study is to provide a working knowledge of the mechanisms related to the interactions of secondarily treated wastewater with natural wetlands and to suggest an approach to the rational design of wetland treatment systems.

A systematic review of nutrient cycling studies in wetlands resulted in the construction of a conceptual model of nutrient dynamics. The following needs were identified: 1) Quantification of hydrological relationships emphasizing the contribution of different water sources to the nutrient budget of the wetland; 2) Mass-balance studies of wetland processes especially decomposition, adsorption phenomena, and peat accumulation; 3) Studies on the role of periphyton in nutrient uptake; and 4) Studies on the nutritional ecology of wetland macrophytes.

The response of different wetland types to wastewater addition was reviewed with emphasis on mechanisms for the removal of nutrients. It was concluded that the major long-term mechanism for the removal of phosphorus is incorporation to peat whereas, denitrification is responsible for most of nitrogen removal. The best nutrient removals were observed in wetlands with thick peat soils and in nutrient limited swamps. Wetlands receiving energy subsidy from tides or waves do not seem to effectively treat wastewater. Environmental alterations due to the addition of wastewater include decreasing diversity and stability with a shift of the trophic relationships towards simpler food chains. It is recommended that an evaluation of the initial wetland quality should be performed in order to avoid using high value wetlands.

The following steps were suggested for an approach to the rational design: 1) Identification of objectives; 2) Identification of time-frame; 3) Assessment of sensitivity to environmental perturbation; 4) Identification of operating mechanisms; and 5) Identification of management options. A discussion of the time element revealed the need for calculation of turnover times of various system components.

The lack of information on many aspects of wetland ecology especially as related to long-term impact of wastewater is considered as a sufficient reason for avoiding their use. If, however, the options are limited, it is recommended that only degraded wetlands should be used and the purpose of management should be to integrate the practice to the overall functions of the landscape. (AA)

1078. Heliotis, F.D. and C.B. DeWitt. 1983. A Conceptual Model of Nutrient Cycling in Wetlands Used for Wastewater Treatment: A Literature Analysis. Presented at the Fourth Annual Meeting of the Society of Wetland Scientists. June 5-8, 1983. St. Paul, Minnesota.

A conceptual model of nutrient dynamics in wetlands use for wastewater treatment provided the basis for reviewing the literature on the subject. Papers were selected in order to describe the storages and transfers of the conceptual model. This approach serves to develop an understanding of wetland systems behavior and allows easy identification of gaps in the literature and of research needs. The response of different wetland types to wastewater addition was evaluated with emphasis on the mechanisms of nutrient removal. The concensus of the literature is that incorporation into peat is the major long-term mechanism for phosphorus removal; that ecological changes reflect the response of the system to nutrient enrichment; and that wetland quality should be evaluated before the application of wastewater. It is recommended that an approach to the design of wetland wastewater treatment systems should include identification of objectives, time frame, operating mechanisms, management options, and assessment of sensitivity to environmental perturbation. (AA)

1079. Hodson, E., A.E. Maccubbin, R. Benner, and R.E. Murray. In press. Microbial Transformation of Detrital Carbon in Wetland Ecosystems: Effects of Environmental Stress. In Ecological Considerations of Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

____. Hyde, H.C., R.S. Ross and F. Demgen. In press. Technical Assessment of Wetlands for Municipal Wastewater Treatment. USEPA Office of Research and Development, Municipal Environmental Research Lab. Cincinnati.

1080. Kadlec, J.A. In press. Wetlands, Wastewater, and Wildlife. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

Wetlands are noted for the diversity and abundance of wildlife that inhabits them. Indeed, it was their importance to wildlife, notably duck and geese, that led to the first (and, for a long time, only) efforts to preserve wetlands and marshes. More recently, other values of wetlands have received increased attention. Of particular concern to us here is the potential use of wetlands for wastewater treatment. Wildlife interests view this possibility with mixed motions -- having battled so long for wetlands preservation, they welcome any help they can get in "selling" the need for wetlands, but they are concerned that this use not destroy the very values they seek to preserve.

Data on the effects on wildlife of wastewater inputs to wetlands are distressingly scarce. As a consequence, the approach adopted herein is to examine the documented and predicted effects of wastewater on wetlands, and then to interpret those effects in terms of their potential impact on wildlife. For convenience, I will categorize wastewater effects on wetland ecosystems in five major categories: 1) primary production, 2) plant community structure, 3) water regime, 4) pathogens, and 5) toxic chemicals. These are not mutually exclusive and there are important interactions among categories, but each category serves to focus attention on a particular set of concerns.

Before commencing a consideration of each of the major effects, a comment about the ubiquity of change in wetlands is in order. Natural, pristine wetlands are dynamic and undergo change at various rates, yet many are essentially permanent features of the landscape. For example, prairie potholes seem to change in a cyclic fashion with patterns of drought, with a time scale on the order of 5-10 years (van der Valk and

Davis 1978), yet they have persisted over a vast area of the northern prairies since the last glaciation, approximately 10,000 years ago. Against that background of natural change, our knowledge of wetland ecosystems strongly indicates that the discharge of wastewater into a wetland ecosystem will produce changes, perhaps dramatic, perhaps subtle, in that system. It might very well change one kind of wetland into a different kind. Both kinds may well be "natural" in the sense that equivalents are found elsewhere as essentially undisturbed systems. A part of this change quite probably will be a change in wildlife. Some species will increase, others decrease. In and of itself, such change is neither bad nor good, but becomes so only in the context of human values and the relative commoness or rarity of these ecosystems in the landscape, usually at the regional, state, or national level. (AA)

1081. Kadlec, R.H. 1983. The Bellaire Wetland: Wastewater Alteration and Recovery. Presented at the Fourth Annual Meeting of the Society of Wetland Scientist. June 5-8, 1983. St. Paul, Minnesota.

The village of Bellaire, MI has discharged wastewater from their stabilization lagoons to a 18 hectare wetland for ten years at about 30 million gallons per year. For the last seven of those years, studies of hydrology, water quality, vegetation and soils have been conducted. Discharges terminated in 1981, with a resultant recovery of the ecosystem. During irrigation, wastewater parameters were dramatically improved by waste treatment standards, but not by receiving ecosystem standards. Mass balances for water and chloride agreed reasonably well. All surface inflows and outflows and precipitation were measured; and evapotransportation was calculated from climatic data. With well-defined hydrology, mass balances were possible for nutrients. Nitrogen, phosphorus, and suspended solids were retained or removed in large measure. After irrigation, no significant release occurred. Vegetation suffered major damage in the immediate vicinity of the discharge; trees were uprooted and new species invaded. Heavy growths of fungi and bacteria were noted in the immediate area of wastewater application.

1082. Kadlec, R.H. In press. Aging Phenomena in Wastewater Wetlands. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

1083. Kadlec, R.H. and D.E. Hammer. 1982. Wetland Utilization for Management of Community Wastewater - 1981 Operations Summary. Houghton Lake Wetlands Treatment Project. Report to the National Science Foundation, Grant ENV-23868. Wetlands Ecosystem Research Group, College of Engineering, The University of Michigan, Ann Arbor MI, 69 p.

1084. Kadlec, R.H. and D.E. Hammer. 1983. Wetlands Utilization for Management of Community Wastewater - 1982 Operations Summary. Houghton Lake Wetlands Treatment Project. Report to the National Science Foundation. Wetlands Ecosystem Research Group, College of Engineering, The University of Michigan, Ann Arbor MI, 67 p.

____. Kusler, J.A. 1980. Regulating Sensitive Lands. Ballinger Pub. Co. Cambridge, MA. 248 p.

____. Kusler, J.A. 1983. Our National Wetland Heritage A Protection Guidebook. Environmental Law Institute. Washington, D.C. 168 p.

1085. Monge, D. 1978. Bibliography of Wetland Values. School of Forestry. State University of New York, Syracuse.

1086. Nichols, D.S. 1983. Capacity of Natural Wetlands to Remove Nutrients from Wastewater. Journal Water Pollution Control Federation. 55(5): 495-505.

Wastewater, even after secondary treatment, is a major source of nutrients that can cause eutrophication of lakes and streams and deterioration of water quality. Conventional advanced wastewater treatment typically requires large capital investments and consumes large amounts of energy. Therefore, interest is increasing in the use of natural wetlands as a simple and energy-efficient means of removing nutrients from wastewater. Wastewater effluent has been applied to many types of natural wetlands from Florida to Canada's Northwest Territories. In all of these studies, some nitrogen and phosphorus was removed from the wastewater as it flowed through the wetland. However, a more quantitative assessment is needed of the capacities and limitations of wetlands to removal nutrients. The purpose of this paper is to review the mechanisms by which wetlands remove wastewater nutrients and to synthesize from data in the literature a model of the relations between wastewater nitrogen (N) and phosphorus (P) application rates and efficiency of N and P removal by wetlands. (AA)

1087. Odum, H.T., In press. Water Conservation and Wetland Values. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

It might be said that the hydrological cycle is the ATP of the biosphere, because of its role in organizing and driving ecosystems. Wetlands are one manifestation of landscape organization by water. Whereas photosynthetic productivity is sometimes used as a basis for evaluating ecosystems, other kinds of work involving the hydrologic cycle may be more important in wetlands. What do wetlands do with water, and how is this related to energy and to regional value? The answers to these questions may affect the way we manage wetlands, preserve them, or generate new ones in making a better mosaic of humanity and nature. (AA)

1088. Reed, S.C. and R.K. Bastian. In press. Wetlands for Wastewater Treatment -- An Engineering Perspective. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

The capability of wetlands to renovate wastewater, as well as tolerate effluent discharges, has been demonstrated in a variety of natural wetland types across the country, as well as in "artificial" or constructed wetlands. This has been well documented elsewhere in a number of state-of-the-art conference and workshop proceedings (Stowell et al., Hantzsche, this volume) and special project reports, such as: a 1978 review by Duffer and Moyer, the proceedings of a multi-agency-sponsored seminar held at the University of California-Davis in September of 1979 (Bastian and Reed 1980), and a literature review of the vegetative and hydraulic processes responsible for wetlands removal of selected pollutants from storm water runoff and treated municipal wastewater by Chan et al. (1981).

Under the right conditions, wetland systems can achieve high removal efficiencies for BOD, suspended solids, trace organics and heavy metals. They have considerable potential as a low-cost, low-energy technique for upgrading wastewater effluents (especially for smaller communities located in areas where natural wetlands abound or ample opportunity for the construction of new wetlands exists). The concept has been shown to be viable and qualifies under current EPA definitions as an innovative technology. Projects which incorporate such technologies are eligible for more federal construction grants assistance than those projects which rely solely on conventional technologies. However, the specific factors responsible for such high treatment levels are not clearly understood at present. Optimum cost-effective criteria applicable throughout the U.S. are not now available for routine design of wastewater treatment systems involving wetlands as a viable part of the treatment facility.

The use of constructed wetlands shows great promise for more general application because, potentially, they are more reliable and involve less risk of adverse environmental impact because of better process control. The potential for a more widespread and routine use of wetland systems (particularly the constructed type) seems high -- if and when reliable, cost-effective, engineering criteria are made available. While considerable information about these systems is already available, the scientific uncertainties over the long-term impacts (beneficial as well as detrimental) of applying municipal wastewater to managed wetland systems can only be clarified through more experience with operational systems. A closely coordinated, multidisciplinary approach involvling the cooperative efforts of experienced engineers, ecologists, biologists, hydrologists, etc. will be required to adequately address the full range of ecological and related issues that must be addressed when designing wetland treatment systems.

The engineering design of a wastewater treatment system is based on a predictable or an assumed set of conditions. The successful performance of that system is then based upon the maintenance of those conditions throughout the useful life of the system -- for most municipal wastewater treatment facilities, this is 20 years. When the conditions cannot be guaranteed, the engineer incorporates a safety factor and overdesigns the system to compensate for the uncertainty. Most of these aspects are more or less under control during the design and operation of a constructed or "artificial" wetland, so the safety factors for this concept can be relatively low. These systems can then reliably treat a relatively large volume of wastewater in a confined space, and the design criteria used can be extrapolated for use in the design of similar systems in the same climatic zone. In natural wetlands, the hydrologic regime is difficult to predict and often impossible to maintain. So a very large safety factor must be incorporated to insure reliable treatment under all conditions. As a result, the wastewater loading will tend to be relatively low and the required wetland area relatively large. Since the hydrologic regime of the natural setting is also subjected to local influences, the extrapolation of design criteria for one natural wetland system to another setting will be difficult. (AA)

____. Richardson, B. (ed). 1981. Selected Proceedings of the Midwest Conference on Wetland Values and Management. June 17-19. St. Paul, Minnesota. Minnesota Water Planning Board; Water Resources Research Center, University of Minnesota; Upper Mississippi River Basin Commission; and Great Lakes Basin Commission.

1089. Richardson, C.J. and D.S. Nichols. In press. Ecological Analysis of Wastewater Management Criteria in Wetland Ecosystems. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

Considerable interest has been focused on the use of wetlands to treat secondary municipal sewage effluent further (Valiela et.al. 1975; Tilton et.al. 1976; Tilton and Kadlec 1979; Odum and Ewel 1980; Lyons and Benforado 1981). Reports on the effectiveness of wetlands in removing nitrogen and phosphorus from effluent have been encouraging (Richardson et.al. 1976; Tourbier and Pierson 1976; Kadlec 1979b; Kadlec and Tilton 1979; Whigham and Bayley 1979), but questions persist about sorption capacity, uptake rates (Richardson et.al. 1978), and long-term capacities of wetland ecosystems to remove nutrients (Richardson 1981; Nichols 1983). This paper presents a series of ecological management criteria that should be addressed prior to the decision to use any wetland ecosystems for treatment of secondary municipal effluent. These criteria include the value of the effluent as a resource, the capacities and limitations of wetlands to accomplish wastewater treatment, wastewater management objectives, wastewater suitability for wetland discharge, and wetland values. Also presented are discussions of wetland hydrology, productivity, cycling of nutrients and heavy metals, and estimates of efficiencies of wastewater nutrient removal by wetlands and the wetland area needed for specific levels of nutrient removal. (AA)

1090. Rusincovitch, F. In press. Use of Wetlands for Wastewater Treatment and Effluent Disposal: Institutional Constraints. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

The Environmental Protection Agency's Office of Federal Activities (Policy and Procedure Branch and 404 Branch) and the Office of Water Programs, in conjunction with the U.S. Fish and Wildlife Service, are considering the use of wetlands to treat municipal wastewater. The impetus for such use is that many small communities have found that "high technology" conventional municipal sewage treatment systems are not well suited to their limited needs.

The primary reason that such conventional municipal treatment systems are often not appropriate for small communities is that they use sophisticated biological and chemical processes to remove biochemical oxygen demand (BOD), suspended solids, and nutrients. Such systems are relatively expensive to operate, especially on a scale suited to small communities and, for the most part, require at least one full time, highly trained operator to work properly. The advantage for larger communities is that higher technology treatment plants can remove pollutants from municipal waste more rapidly and require much less land area than the less technical, less expensive, more "natural" systems, such as stabilization ponds. (AA)

1091. Shiaris, M.P. In press. Public Health Implications of Sewage Applications on Wetlands: Microbiological Aspects. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

With an ever expanding population, demand for water for urban agricultural, and industrial use is growing. At the same time, the volume of biological and chemical wastes which enter our waters is also increasing. The impending dilemma requires a switch to increased and more efficient water recycling. The potential use of wetlands as wastewater treatment sites is a promising approach (U.S. EPA 1979, Kadlec and Tilton 1979); hence, the subject of this workshop.

Any future application of sewage to wetlands must be free of unreasonable risks to public health. As a rule, untreated municipal wastewater contains many components which pose a threat to the well-being of wildlife and humans. Pathogens from human and animal feces, organic toxins, industrial waste, heavy metal, and pesticides are present in varying amounts in all municipal sewage. A variety of specific treatments to attain a satisfactory water effluent are available. The projected use of the recycled wastewater and the potential for human contact will dictate which treatment and the degree of treatment necessary to reduce the health risk (Shuval 1982).

Microorganisms are of paramount importance in any public health consideration of wastewater. Clearly, the direct hazards of microorganisms as agents of disease in wastewater are well recognized if not fully understood. The role of microorganisms as agents of biotransformations, however, is not as well recognized and certainly not as well understood relative to public health. In a wetlands treatment site, the microbial component may actively detoxify hazardous chemicals and, conversely, may transform or "activate" some relatively nontoxic chemicals to more toxic forms.

The present purpose is to highlight briefly the potential health risks of microorganisms and microbial activities in sewage wastewater. Relatively little information is available on the public health hazards that may be encountered by applying wastewater to wetlands. On the other hand, there is considerable information on land application health aspects which have been reviewed elsewhere (Lance and Gerba 1978; Kowal, in press; Pahren et.al. 1979). Regulatory authorities postulate that the health risks for wetland systems will not be greater than the hazards encountered in conventional wastewater treatment, assuming that materials will not be harvested for human consumption (U.S. EPA 1979). Therefore, while most of the work discussed herein was not conducted in wetland systems, it will be assumed that the health risks discussed are applicable to wetlands as well. (AA)

1092. Sutherland, J.C. In press. Wetland-Wastewater Economics. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

In the mid-1970's, there was a great need in Michigan for economical, post-secondary wastewater treatment, including phosphorus removal. Wetland application for removal of phosphorus from this community's stabilization pond effluent seemed an affordable alternative. By early 1976, four years of research under the direction of Dr. Robert Kadlec of the University of Michigan at the Porter Ranch peatland near Houghton Lake, Michigan indicated excellent renovation of wastewater and nitrogen species by wetland application (Kadlec et.al. 1976).

If it had not been for Natural Science Foundation (NSF) support, a full-scale wetland treatment project at Houghton Lake might never have been developed. Nothing like it had been done before in Michigan. The U.S. EPA had never funded design and construction of a wetland treatment project through the Municipal Construction Grants program, and state and federal review agencies had understandable concerns for the integrity of this pristine natural wetland. The factors that brought success to the project were excellent P-removal potential, prospects for net positive environmental responses, an informed local populace, and great projected savings in wastewater treatment costs. The construction cost for the wetland at Houghton Lake was projected, in 1976, to be $600,000. The construction of the upland irrigation alternative was projected at $1.1 million or 83% higher. The construction of the wetland wastewater facilities, in fact, cost approximately $400,000 (1978 dollars).

By early 1976, the NSF project officer, Dr. Edward Bryan, thought it time to develop the general economic feasibility picture. Williams and Works, Inc. was selected to begin such a study, limited to Michigan (Sutherland 1977). At that time, we have more questions than information. One of the questions was what kind of pretreatment assumption should be made. It seemed reasonable to think of secondary treatment as the minimum pretreatment requirement for natural wetlands. Natural wetlands, in general, were perceived to be highly sensitive to cultural use. Also, there was great need in Michigan for economical, post-secondary treatment, including phosphorus removal. The use of either wetlands or upland irrigation for phosphorus removal would be achieved primarily by small rural and resort communities in Michigan. There are only a few large communities located near the extensive tracts of undeveloped upland or wetlands needed, but there are many small communities with wastewater flows of less than 0.5 million gallons per day (MGD) that are so located. And a great number of these were already committed to secondary treatment by stabilization ponds.

We found that wetlands of significant size located within 10 miles of secondary treatment facilities were all bordered by streams and rivers. The size of wetlands we had in mind would be such that all of a community's wastewater could be applied at less than one inch per week during a 6-month season. Stabilization ponds would store the wastewater during the 6-month off-season. Ten communities were selected to evaluate in detail. The ten had wastewater flows in the range of about 40,000 gallons per day (GPD) to 350,000 GPD. All were located near wetlands large enough to apply wastewater at the rate of less than 1 inch/week. It was assumed that state-owned wetlands would be free, that privately-owned wetlands would be $550/acre (updated to 1982), and that a gated irrigation pipe would be used for applying wastewater to the wetland based on the developing design for Hougton Lake. It was also assumed that chlorination and dechlorination facilities would be needed and, of course, transmission forceline from ponds to wetland would be like any other conventional wastewater forceline. Very few small Michigan communities are served with biomechanical secondary treatment systems; however, the economic projections should apply to wetland treatment of secondary effluent in general. (AA)

1093. U.S. Environmental Protection Agency. 1983a. Freshwater Wetlands for Wastewater Management. Environmental Impact Statement. Phase I Report - EPA 904/9-83-107. Region IV, Atlanta.

The understanding of wetlands values and functions has increased significantly during the past decade. During that period more attention has also been given to the use of wetlands for wastewater management. With increased pressure placed on wetland systems in recent years, regulatory and ecological issues have been raised. This EIS is designed to develop tools that can assist local, state and federal agencies in making wastewater management decisions affecting wetlands.

1094. U.S. Environmental Protection Agency. 1983b. The Effects of Wastewater Treatment Facilities on Wetlands in the Midwest. Technical Report. Region V 905/3-83-002. Chicago, Illinois.

The purpose of this report is to provide background information for use in the preparation of a Generic Environmental Impact Statement on wastewater management alternatives. Both natural and constructed (artificial) wetlands are considered for this alternative wastewater treatment technology. The report describes issues of wastewater and wetlands in the Midwest States (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin), summarizes the existing literature on wastewater impacts to wetlands (includes a bibliography), inventories the 98 existing wetland discharges in EPA Region V, and identifies potential sites and topics for additional study. Key topics for future study include: constructed wetlands, hydrologic impacts, long-term ecological effects, legal and administrative constraints, mitigation of impacts, management of receiving wetlands, and disease and health considerations.

1095. U.S. Environmental Protection Agency. 1983c. Wetlands Treatment: A Practical Approach. EPA Emerging Technology Series.

This EPA brochure briefly introduces the practical possibilities of wetlands treatment of wastewater. Use of natural versus constructed wetlands is differentiated. Treatment systems design features are summarized. A list of currently operating wetland system is presented. Potential limitations of wetland use for wastewater treatment are noted. Costs, both capital and O&M are briefly presented.

1096. Whigham, D.F. In press. Vegetation in Wetlands Receiving Sewage Effluent: The Importance of the Seed Bank. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

Van der Valk (1981, 1982) has proposed a model for studying changes in wetland vegetation that is based on three life history attributes: (1) life span, (2) propagule longevity, and (3) propagule establishment requirements. The model assumes that knowledge of these attributes for species in a wetland would enable one to predict vegetation composition under various hydrologic (and other environmental) conditions. Although the model needs to be modified or expanded to permit quantification of population properties (e.g., biomass, aerial coverage, etc.), it provides a suitable framework to evaluate the types of changes that might occur when wetlands are used for wastewater management.

The purpose of this paper is to discuss the effects that wastewater application might have on wetland vegetation. Because two of the three attributes used in Van der Valk's model relate to the seed bank, the paper will focus primarily on the effects that altered hydrologic and nutrient patterns have on recruitment from the seed bank. (AA)

1097. Wile, I., G. Miller and S. Black. In press. Design and Use of Artificial Wetlands. In Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Proceedings of a Workshop June 23-25, 1982. University of Massachusetts, Amherst, MA. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency.

In recent years, the use of wetlands for wastewater treatment has received increasing attention in North America. To date, attention has largely focused on the use of natural wetlands for tertiary treatment.

Artificial wetlands, however, offer greater scope for general use and are not restricted by many of the environmental concerns and user conflicts associated with natural wetlands. Unlike natural wetlands, which are confined by availability and proximity to the sewage source (Sutherland 1981), engineered marshes can be built anywhere, including lands with limited alternative uses. They also offer greater scope for design and management options and thus may provide superior performance and reliability.

Use of artificial wetlands for year-round treatment of sewage has been under study in Ontario since 1979. An experimental facility in Listowel, Ontario consists of five separate marsh systems (Figure 1) and provides flexibility in pretreatment (conventional lagoon; complete mix aerated cell), system configuration, hydraulic loading rates, liquid depths and detention times (Wile, Palmateer and Miller 1981; Black, Wile and Miller 1981). Data from this facility has been used to develop preliminary design and management guidelines. (AA)

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